

S. HRG. 111-984

THE FUTURE OF U.S. HUMAN SPACEFLIGHT

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED ELEVENTH CONGRESS

SECOND SESSION

MAY 12, 2010

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED ELEVENTH CONGRESS

SECOND SESSION

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CONTENTS

Hearing held on May 12, 2010	Page 1
Statement of Senator Rockefeller	1
Statement of Senator Hutchison	3
Prepared statement	5
Statement of Senator Nelson	6
Prepared statement	8
Prepared statement of Captain James A. Lovell, USN (Ret.), Commander, Apollo 13, submitted by Hon. Bill Nelson	71
Statement of Senator Vitter	8
Statement of Senator LeMieux	9
Statement of Senator Brownback	10
Statement of Senator Johanns	11
Statement of Senator Pryor	12
Prepared statement	12
Statement of Senator Warner	43

WITNESSES

Hon. John P. Holdren, Ph.D., Director, Office of Science and Technology Policy, Executive Office of the President of the United States	12
Prepared statement	14
Hon. Charles F. Bolden, Jr., Administrator, National Aeronautics and Space Administration	17
Prepared statement	19
Neil A. Armstrong, Retired Astronaut, Former Commander, Apollo 11	45
Prepared statement	46
Captain Eugene A. Cernan, USN (Retired), Commander, Apollo 17, Astronaut (Retired)	49
Prepared statement	52
Norman R. Augustine, Chairman, Review of U.S. Human Spaceflight Plans Committee	54
Prepared statement	57

APPENDIX

Response to written questions submitted to Hon. Charles F. Bolden, Jr. by:	
Hon. Kay Bailey Hutchison	75
Hon. Barbara Boxer	82
Hon. Amy Klobuchar	82
Hon. Mark Warner	83
Response to written question submitted to Norman R. Augustine by:	
Hon. Kay Bailey Hutchison	91
Hon. Amy Klobuchar	93

THE FUTURE OF U.S. HUMAN SPACEFLIGHT

WEDNESDAY, MAY 12, 2010

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Committee met, pursuant to notice, at 2:35 p.m. in room SR-253, Russell Senate Office Building, Hon. John D. Rockefeller IV, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. JOHN D. ROCKEFELLER IV, U.S. SENATOR FROM WEST VIRGINIA

The CHAIRMAN. This hearing will come to order.

Our space program is clearly at a turning point. Earlier this year, the Obama Administration charted a new course. They had been working on it for a long time. And I know there is a lot of uncertainty and disagreement and all kinds of things about that, particularly when it comes to proposed plans for human spaceflight. This hearing is an important opportunity to take a close look at those plans and others.

I have said before in this committee and I have addressed it directly with Administrator Bolden during his confirmation that I believe from my personal point of view that we need a new direction. To many, including myself, defenders of the status quo for NASA, be they many or be they few, seem to justify their views solely based on job impact. I do not think we can afford to do that. Jobs in West Virginia are subject number one, two, three, four, five, six, and seven, and always will be. This is a national and international program that we are talking about. I think we have to strike a balance between economic development, which means jobs, and modernizing our space program so we can remain competitive for years to come.

NASA's first mission must be to do what is best for the Nation. The American people deserve the most from their space program. NASA's role cannot stay static. The President has challenged the U.S. Government to seek greater international collaboration, enable commercial services, and develop new exploration technologies, and on top of that, I would include vastly expand research. You are doing something up there right now, including medical research on MRSA, which kills thousands and thousands of people every year in this country, broad research, technical research, engineering research, all kinds of research. There is no better place to do it. And I think we have to develop new exploration technologies.

So these are good priorities and they should help ensure that in tough fiscal times, we build our space future in a measured, relevant, innovative and sustainable way. And this is not going to be easy. One reason it is not going to be easy is because we are under a, more or less, flat-line budget. Most Americans do not know that. I think most of them would welcome it if they did know it, but for those of us who work in Government and want to push programs forward, that is a hard pill to swallow. That does not affect the Defense Department. It does not affect the intelligence community. It affects only parts of the veterans community.

But NASA's current budget of \$18 billion may be a high water mark. We do not know what a soft freeze means. But it may be a high water mark for years to come. So we have to live with that and make the most of it. We cannot assume the agency will have unlimited resources for every mission it wants to undertake. So, therefore, we have to make hard choices.

Today I look forward to a robust evaluation of the agency's plan for human spaceflight, but more than that, we have to measure and shape those goals against our greater national priorities for the years and the decades ahead. I really feel strongly about that. NASA's research in aeronautics helped create our global leadership in aviation. We need its scientific minds to be involved in solving today's and tomorrow's challenges in energy, medical research, robotics. I have talked about these things. I really mean them.

In addition, we need to understand how it will support our workforce and protect our industrial base, ensure our national security, and strengthen international relationships. And we have to examine how we use human spaceflight as an important tool of smart power, exemplified by the International Space Station partnership and strong U.S. and Russian participation.

So efforts like this can build stability, and they can ensure global access to space and help us move forward toward greater transparency as we establish the rules of the road, which is what I think we are here to do.

I know that our focus today is specifically on human spaceflight. I recognize that, but I do not want anybody to forget the agency's broader priorities which include exploration, science, aeronautics, education, technology, research of any and all kinds. These are the foundations of our future. They are enormously important and I hope the agency finds that balance and moves forward again. I also hope that we will increase our focus on tying NASA's human spaceflight efforts to benefits in these areas.

I want to thank all of our witnesses today, including those who will follow, the two that sit before us now, both extremely distinguished Americans, including Mr. Neil Armstrong, Commander of Apollo 11; and Eugene Cernan, Commander of Apollo 17. We thank them for their service.

In the past, I should say in ending, I have been critical of NASA's financial and program management. I am still that way. As we move toward reauthorization, I firmly believe this committee has a huge oversight role to play. NASA cannot continue down the same path in my judgment.

I turn now to my distinguished partner, Senator Kay Bailey Hutchison.

**STATEMENT OF HON. KAY BAILEY HUTCHISON,
U.S. SENATOR FROM TEXAS**

Senator HUTCHISON. Thank you, Mr. Chairman. I am very pleased that we have this hearing because I have been alarmed at the plans that have been put forward, not with the goal of the plans. I agree with the goal. We should utilize space for science and research that cannot be done in the gravity conditions on Earth, and we need to be bold in exploring space so that we maintain our superiority in space exploration.

I appreciate, obviously, the two of you: General Bolden, you have been an astronaut and have a distinguished career and are now the NASA Administrator, and Dr. Holdren from the White House Office of Science and Technology Policy. And I am very pleased, Mr. Chairman, that we do have the first man who walked on the Moon and the last man who walked on the Moon on our second panel, Neil Armstrong and Eugene Cernan, along with Norm Augustine who was tasked by the President to come up with options that would save NASA, our space exploration, and putting humans in space.

I find serious flaws in the areas where detailed information has been provided by the Administration. There are good reasons to have reservations about a proposal that discards billions of dollars of important technology and engineering advancements paid for by American taxpayers and puts us on a course that relies on a still developing commercial market to fill a role carried on for more than 5 decades by the world's preeminent space agency.

Our 50-year legacy of leadership in space is on the line, and we need to have a credible plan to make the next step forward, enhancing our investment over the last 5 decades.

We will get to Mars by building upon our existing capabilities, including our infrastructure, prior investment, and the most skilled workforce in the world.

We do not need a Presidential commission to manage the transition of NASA workers to other jobs or other places. We need a plan that preserves their extraordinary talents and challenges them to work on new goals and technologies to build a bridge from where we are to where we want to be.

Every assumption in the President's proposal that is made about the potential development of a new technology or the emergence of a customer base beyond NASA to support a fledgling commercial space industry is another source of risk and another point of potential mid-program failure that could undermine our human spaceflight capability.

We must leverage our existing capabilities and workforce to reach our goal. That is why for me, the discussion begins with the International Space Station, which underpins our reason to send humans into space in the short- and mid-term while we work on new technologies to take us deeper into space.

Flying out the Shuttle program on the current schedule before performing the analysis of the parts and equipment the International Space Station will need to extend the life of the station from 2015 to 2020, which is the President's goal, is a risk. It is particularly risky when those potential needs have not been mapped against the existing or anticipated cargo capabilities that will pro-

vide our only means to bring cargo to the station in a world without the Space Shuttle.

I have proposed stretching out the remaining Shuttle missions over the next 2 years and adding the Launch on Need flight as an actual flight with available cargo capabilities. That would allow for the analysis and planning that we must have to minimize the risk to the ISS, the International Space Station, and bridge the gap that has been a concern of mine and also Senator Nelson's since it was first proposed 4 or 5 years ago.

The space station provides our primary reason for current and future spaceflight and offers almost the entire business case for many of the emerging commercial space companies in the short run. Safety has been asserted as a reason to stop the Shuttles this year.

But, first, I am not proposing we add more, just spread them out over a longer period of time, 2 years.

Second, I do not accept arguments that a *Soyuz* vehicle our engineers have never had complete access to for study and certification is safer than the Space Shuttle to carry our astronauts to and from the station. It is time to have an honest conversation about the Space Shuttle and its importance to our short-term capabilities.

I am hopeful that Dr. Holdren and General Bolden can finally answer some key questions on behalf of the Administration today, including: have we taken every step possible to reduce the risk to the space station? How will the technology and engineering advances from \$9 billion of investment in the Constellation program be leveraged and utilized if the program is discontinued? Why ignore the actual options laid out in the Augustine Committee report and why wait until 2015 for the selection of a heavy lift vehicle design? What will happen if we do not have a NASA-owned and managed capability like Constellation or some iteration of Constellation and private providers struggle with cost overruns and ultimately fail? Will American taxpayers have to bail out these companies? What other option would we have at that point except to continue paying whatever it takes to build the vehicles because the NASA capability has been dismantled? Why not reform NASA's contracting practices rather than putting all our emphasis on a still developing commercial sector that may not be able to deliver?

Mr. Chairman, those are just a few of my questions. Between the proposal I have advanced, the thoughts of other members, and the recommendations in the Augustine report, there are many ideas about how to reach bold new goals.

American exceptionalism demands that we do better than the proposal that has been put forward that does not have the plans to implement it in a safe and secure way.

Mr. Chairman, I would just say that I stand ready to work with the Administration. I would like for this Administration to have the legacy of continuing our preeminence in space. I do not think the proposal that has been put forward will do that, but I certainly would like to work in a bipartisan and certainly collegial way to achieve a goal that I think is the same as the President's. I do not think he is putting forward the plan to achieve the goal, and I want to help put that together so that we will spend our taxpayer

dollars wisely. We will not throw away the billions that have already been spent.

So the space station, which now has eight contracts waiting to go up through NIH and the Department of Agriculture to utilize the space station—there will be more if everyone knows that there is true availability of the space station with a Shuttle that we can control and know that if there is a gap, it will be a short gap, not a 5 to 8 and possibly 10-year gap as we have new fledgling commercial activities that attempt to do things that have already been tried and proven or disproven in the NASA history.

So, Mr. Chairman, I do thank you for the hearing, and I hope that it leads us to a better consensus that we can work together toward our shared goal. Thank you.

[The prepared statement of Senator Hutchison follows:]

PREPARED STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

Thank you, Mr. Chairman, for holding this hearing. We are fortunate to have such an exceptional panel of witnesses.

Two of our witnesses require no introduction. Their vision and courage are legend, and upon their shoulders several generations of American astronauts have stood to reach for the Heavens. I speak, of course, of Neil Armstrong and Eugene Cernan.

We are also joined by my friend Norman Augustine, who led a review of the U.S. human spaceflight program; General Charles Bolden, the current NASA Administrator; and Dr. John Holdren, who heads the White House Office of Science and Technology Policy.

If we are to work through the difficult issues ahead to arrive at a consensus path for America's space program, this hearing represents an excellent place to begin.

Lack of Information and Substantial Risk

Mr. Chairman, I have said a lot in recent weeks about the President's proposal for NASA. Many Members of Congress find serious flaws in the few areas where detailed information has been provided.

There are good reasons to have reservations about a proposal that discards billions of dollars of important technology and engineering advancements paid for by American taxpayers, and places us on a course that relies on a still developing commercial market to fill a role carried on for more than five decades by the world's preeminent space agency.

In listening to the President and members of his Administration discuss their proposal, I have repeatedly heard the words *might*, *could*, and *may* to describe a bold future and the elements of a framework to get us there.

The one word I keep waiting to hear, Mr. Chairman, is *how*!

Our 40-year legacy of leadership in space is on the line and we need to have a credible plan to take the next step forward, enhancing our investment over the last four decades. *And let me be clear, a destination is not a policy, and hope is not a plan!!*

Assumption Equals Risk; Need to Build on Existing Capabilities

We will get to Mars by building upon our existing capabilities, including our infrastructure, prior investment, *and the most skilled workforce in the world.*

We do not need a Presidential Commission to manage the transition of NASA workers to other jobs, or other places. We need a plan that *preserves their extraordinary talents* and challenges them to work on new goals and technologies to build a bridge from where we are to where we want to be, and with the least possible risk to our exploration programs.

Every assumption in the President's proposal that is made about the potential development of a new technology, or the emergence of a customer base beyond NASA to support a (47th fledgling commercial space industry, *is another source of risk, and another point of potential mid-program failure that could undermine our human spaceflight capability.*

We must leverage our existing capabilities and workforce to reach our goal.

Preserve the Station and Build from There

That is why, for me, this discussion begins with the International Space Station (ISS), which underpins our reason to send *humans into space in the short and mid-term* while we work on new technologies to take use deeper into space.

Flying out the Shuttle program on the current schedule *BEFORE performing a comprehensive analysis of ISS equipment and part needs to extend its life until 2020, is a risk*. It is particularly risky when those potential needs have not been mapped against the existing, or anticipated, cargo capabilities that will provide our only means to bring cargo to the station in a world without the Space Shuttle.

I have proposed stretching out the remaining Shuttle missions over the next 2 years and adding the Launch on Need (LON) flight as an actual flight with available cargo capabilities. That would allow for the analysis and careful planning *I believe is needed to minimize the risk to the ISS and bridge part of the gap to new capabilities*.

The space station provides our primary reason for current and future spaceflight and offers almost the entire business case for many of the emerging commercial space companies in the short run. Safety has been asserted as a reason to stop the Shuttles this year. But first, I am not proposing we add more—just spread them out over a longer time frame—two years. And, second, I do not accept arguments that a *Soyuz* vehicle our engineers have never had access to for study and certification is safer than the Space Shuttle to carry our astronauts to and from the station. *It is time to have an honest conversation about the Space Shuttle and its importance to our short term capabilities*.

Lots of Questions Need To Be Addressed

I am hopeful that Dr. Holdren and General Bolden can finally answer some key questions on behalf of the Administration today, including:

- Have we taken every step possible to reduce the risk to the space station?
- How will the technology and engineering advances from \$9 billion of investment in the Constellation program be leveraged and utilized if the program is discontinued?
- Why ignore the *actual* options laid out in the Augustine Committee report, and why wait until 2015 for the selection of heavy lift vehicle design?
- What will happen if we do not have a NASA-owned and managed capability like Constellation and private providers struggle with cost overruns and ultimately fail?
- Will American taxpayers have to bail out these companies? What other option would we have at that point except to continue paying whatever it takes to build the vehicles?
- Why not reform NASA's contracting practices rather than putting all our emphasis on a still developing commercial sector that may not be able to deliver?

Conclusion

Mr. Chairman, those are just a few of my questions. Between the proposal I have advanced, the thoughts of other members, and the recommendations in the Augustine report, there are many ideas about how to reach bold new goals in manned space exploration.

The burden lies with the Administration to demonstrate why the President's proposal is superior to all of these other ideas.

American exceptionalism demands more . . . the brave men and women that climb aboard rockets to explore the frontiers of space require more . . . and, future generations of American children deserve more!

Thank you again for holding this hearing. I look forward to the testimony.

The CHAIRMAN. Thank you, Senator Hutchison.

I now call on the Subcommittee Chair and that is Senator Nelson from Florida.

STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Senator NELSON. Thank you, Mr. Chairman.

Mr. Chairman, there is a great deal that is riding on this hearing today because we are preparing the way for us then to start the markup in your subcommittee of the authorizing legislation, and

this is being done in the midst of a great deal of uncertainty about the future of NASA. We are very fortunate to have the witnesses that we have at the table who clearly ought to give us some direction, and we are very fortunate to have the three that will follow on the next panel.

This is such an important hearing because there are people all across the country, including this extraordinary family called the "NASA family" that has spaceflight in their genes that are looking to us to exercise our legislative and appropriations function in helping the President and the Executive Branch chart the course of where America's human space program is going from here.

Now, there have been a lot of us that have given a lot of advice to the President, and I think in large part his speech down at the Kennedy Space Center reflected that. We asked that he consider a strong vision statement. In fact, we specifically said a vision of going to Mars. And he did that.

We asked that he consider not the cancellation of the Constellation program, but the restructuring of it, and in fact, we wanted that to have the capability of giving us flexibility in the future. And we received that from his statement.

We asked for the extension of the International Space Station's life, instead of it being cutoff in 2015 as previously planned. I mean, we are just completing it now, and it is 2010. Obviously, you do not want to shut it off 4 years down the road. And we received that commitment from the President.

Some of us asked that since there is the hardware ready for an additional Shuttle flight, that he consider that. And although he did not announce that in his speech down at the Kennedy Space Center, it is my hope that that is under consideration in the White House and NASA at this point.

We also asked the President for the safe completion of the current Space Shuttle manifest even if it has to be flown into next year and that the increases in funding for the other critical parts of NASA's budget, including science and aeronautics and Earth observation and the breakthrough research and development be there. And he has proposed that.

But the authorizing and the appropriating committees continue to review the President's proposal. We here in the legislative branch are going to try to continue to work with the Administration to refine his plan and change some parts of it. And it is in that spirit that we come here today to take a deeper look into the details of the proposal, and specifically some of us are going to explore how the plan relates to national priorities such as education and innovation and security, the implications of the plan, including the impacts on national security, the workforce, the industrial base, and our international posture. And we are going to look at the plan's overall integration, including the schedule and the cost.

So then we are going to be looking, Mr. Chairman, at the President's proposal to make a decision on a heavy lift vehicle solution, of which he said is as late as 2015. We would like to speed that up. We want to establish the rationale of such a proposal and where the benefits and the challenges lie.

Thank you, Mr. Chairman.

[The prepared statement of Senator Nelson follows:]

PREPARED STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Mr. Chairman, while I'm pleased by the fact that during his recent visit to the Kennedy Space Center President Obama showed that he does in fact recognize the need for a robust human spaceflight program, I feel there remains some room for improvement in his proposed plan for our future in space.

I've spent a great of time advising the President and his Administration on how best to move NASA forward—from his recent speech in Florida it's obvious the President has been listening.

I asked that we receive a strong a vision statement, delivered by the President, defining *Mars* as the ultimate goal—we received one.

I asked for the restructuring of the Constellation Program, to include the development of a heavy-lift vehicle and a crewed vehicle capable of evolving to support expeditions beyond low-Earth orbit—we received it.

I asked for the extension of the International Space Station's operational life until at least 2020—we received it.

And I asked for the development of a robust commercial space sector and we are now taking steps in that direction.

I'm also pleased that the President's plan takes care to provide for *the safe completion* of the current Space Shuttle manifest, even if it must be flown into 2011, and that it increases funding for the other critical parts of NASA's budget including science, aeronautics, Earth observation, and breakthrough research and development.

However, the authorizing and appropriating committees continue to review the President's proposal and we in Congress are continuing to work with the Administration to refine his plan.

And it is in that spirit that today we take a deeper look into the details of the proposal. Specifically, we'll explore how the plan relates to national priorities, such as education, innovation, and security; the implications of the plan, including impacts on national security, workforce, the industrial base, and our international posture; and the plan's overall integration, including schedule and cost.

Lastly, we'll also discuss the President's proposal to make a decision on a heavy-lift solution as late as 2015. We want to establish the rational of such a proposal and where its benefits and challenges might lie.

Thank you Mr. Chairman—I look forward to a productive hearing.

The CHAIRMAN. Thank you, Senator Nelson.

Senator LeMieux, I was going to call on you but I should call on Senator Vitter because he is Ranking on the Subcommittee. Senator Vitter?

STATEMENT OF HON. DAVID VITTER,
U.S. SENATOR FROM LOUISIANA

Senator VITTER. Thank you, Mr. Chairman. Thank you for this hearing. It is a very important hearing. I agree with my colleague on the Subcommittee. And the stakes are very high.

I will submit my full opening statement for the record. It underscores what I have said very clearly before, that I am extremely concerned by this plan and budget submission for NASA by the Administration. I think it should be very concerning to the entire space community and the American people.

My fundamental concerns are these three.

Number one, I am convinced it will absolutely relinquish our leadership role in human spaceflight certainly for our lifetimes, maybe longer, if we follow down the proposed path.

Number two, I repeat Senator Hutchison's comments. I think complete reliance on the commercial sector is a bad idea because there is absolutely no evidence that that sector alone can supply this capability in the near term. I want to support that sector. I

want to see that capability grow, but not put all of our eggs in one basket on that long bet.

And number three, I really think we would be in the process, if we adopt the plan, of fundamentally changing NASA and making it a research institution almost solely. Mr. Chairman, you mentioned the broad category of NASA missions, and we should remember all of them, but we should start with the core mission which is exploration in human spaceflight. I think this proposal is forgetting, to a large extent, about that absolutely core, central mission and putting too much emphasis on other ancillary missions.

I welcome all of our panel, certainly these distinguished gentlemen, and our second panel. But, Mr. Chairman, I would just make one suggestion, which is, I think, the original idea is to have our other three panelists go first so that we can get into more of a conversation and get more reaction from the Administration officials on their very compelling testimony, in my opinion. We have heard from the Administration before several times about the new vision, about the budget submission. I am happy to hear from them again, but I honestly think it would be far more productive of real discussion and new ideas to have the other three panelists go first, to have the Administration listen, and to have all of us respond to that. So that would be my suggestion to the chair.

The CHAIRMAN. I welcome that, and should you become Chairman some day, you can arrange that.

[Laughter.]

The CHAIRMAN. Senator LeMieux, Senator Brownback, Senator Pryor, and my favorite Governor down there, Senator Johanns, if you could keep your remarks to about 3 minutes. Senator LeMieux?

**STATEMENT OF HON. GEORGE S. LEMIEUX,
U.S. SENATOR FROM FLORIDA**

Senator LEMIEUX. Yes, sir. Thank you, Mr. Chairman, and thank you, Ranking Member Hutchison, for holding this hearing today.

General Bolden, Dr. Holdren, thank you for your service and for being here.

I, like my colleagues, want to work in a collegial way with the Administration in order to make sure that we continue our leadership role in space, but I unfortunately cannot take as optimistic of a view of the President's plan.

For nearly 50 years, we have been the undisputed leader in space exploration. The proposal by the Administration to, what I would call, kill the Constellation program, its Aries I and Aries V rockets, and turn the *Orion* vehicle into a speculative lifeboat will be, in a word, devastating. That is not my word. That is the word used by the commanders of Apollo 11, 13, and 17. It is going to be devastating for, I think, three main reasons.

One, with the termination of the Shuttle, we will be, for the first time in nearly 50 years, for a period of years unable to go into low-Earth orbit, and we will put ourselves at the mercy of the Russians.

Second, we are going to dismantle a world-class workforce that will be virtually, if not completely, impossible to reconstitute.

Third, we are going to relinquish our status as leaders and pioneers in space exploration. I do not look forward to the day when I will explain to my children why the Chinese are putting their flag on the Moon over ours. We have spent nearly \$10 billion on the Constellation program, and while it is not a perfect project, it is the law of the land. Mr. Chairman, I think it is worth noting that Congress has been clear in reauthorizing this program twice, in 2005 and 2008, with a democratically-controlled Congress and a Republican controlled Congress.

Additionally, language was specifically included in the 2010 omnibus appropriations bill prohibiting the cancellation of the Constellation program. One thing I look forward to discussing in our questions is letters and documents I have received about the programs within Constellation already being canceled. To date, no laws have changed, and Congress has not taken action to enact the changes proposed by the Administration.

We read in the *Wall Street Journal* even today, about these programs being canceled.

My view is that we need to stay on course with American human space exploration. We need, as my colleagues have suggested, to extend the Shuttle to ensure the U.S. has access to space. We need to expedite completion of the Aries I rocket to ensure access to low-Earth orbit and the International Space Station. And finally, we need to expedite the development of a heavy lift vehicle and not wait, as my colleagues have said, until 2015.

The United States leads the world in space exploration. It is one of our Nation's qualities that is admired around the world. We cannot and should not cede an inch of it to other countries. If we fail to act now, the President and this Administration will be remembered for killing America's leadership in space exploration, and to me, Mr. Chairman, that is not acceptable.

Thank you.

The CHAIRMAN. Thank you, Senator. And that was absolutely perfect timing.

Senator Brownback?

**STATEMENT OF HON. SAM BROWNBACK,
U.S. SENATOR FROM KANSAS**

Senator BROWNBACK. Thanks, Mr. Chairman. Thanks for the hearing.

I am certainly a strong supporter of NASA. I was Chair of the Subcommittee some years ago. This is a great topic and it is very timely that you are putting this together.

I look forward to working with you and other members on the space program and these issues.

I am a strong supporter of NASA, as I mentioned, and of the commercial space industry, and I have a steadfast belief that the United States needs a vision for the U.S. space program. I have been a proponent of phasing out the Space Shuttle and to use the resources for alternative deep space ventures and cutting edge research. With the impending retirement of the Shuttle, NASA is now assuming a much different role than in our past space effort, and I think there is great opportunity to have a space program that leads the world, but it will be a space program that is firmly em-

bedded in opportunity for all. By opening up commercial space, it ensures a strong future for the U.S. in the competitive aerospace industry.

Mr. Chairman, you have assembled an exceptional panel of experts. I met with Mr. Augustine 2 weeks ago. You could not get a better guy to talk about this who has been around it a long period of time and sees the budget realities that we are in right now. As you have mentioned, we have a tight budgetary atmosphere and we have got to be able to fit our goals and our dreams and our desires within that. I think what he sees is that we need to be able to integrate commercial space into doing things into low-Earth orbit and then for NASA to move on from that point.

I think there is a lot of room for discussion here, and it is an important discussion to have for us to move forward as a space-faring Nation and as a Nation that leads in space. We can do it, but I think it is going to have to be under a different design than what we have been doing.

And I look forward to the discussion of that design.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

And Senator Johanns?

**STATEMENT OF HON. MIKE JOHANNNS,
U.S. SENATOR FROM NEBRASKA**

Senator JOHANNNS. Thank you, Mr. Chairman.

Let me, if I might, just offer a very brief thought. Like most Americans, I grew up with a tremendous amount of admiration for Neil Armstrong. I thought this man and really all the astronauts were just enormously courageous individuals. Therefore, you can only imagine that I would give his testimony a great deal of weight as I think about this hearing and prepare for it.

Early on in his testimony, he said something that to me was very compelling and very concerning. He said, "With regard to President Obama's 2010 plan, I have yet to find a person in NASA, the Defense Department, the Air Force, National Academies, industry, or academia that had knowledge of the plan prior to the announcement. Rumors abound that neither the NASA Administrator nor the President's Science and Technology Advisor were knowledgeable about the plan. Lack of review normally guarantees that there will be overlooked requirements and unwelcome consequences. How could such a chain of events happen? A plan that was invisible to so many was likely contrived by a very small group in secret who persuaded the President that this was a unique opportunity to put his stamp on a new and innovative program. I believe the President was poorly advised."

If, in fact, that is the way that this was brought about, that is enormously concerning. Where does this come from is the question that I have to ask. So it is not only the concerns expressed by Senator LeMieux and others about what is happening here, it is the method and manner by which we got there. Once again, it appears a complete lack of transparency in the Administration and there is just too much of that.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator.

Senator Pryor?

**STATEMENT OF HON. MARK PRYOR,
U.S. SENATOR FROM ARKANSAS**

Senator PRYOR. Thank you, Mr. Chairman. Mr. Chairman, I want to thank you for having this hearing and, Senator Hutchison, for your leadership on this. I have to acknowledge Senator Bill Nelson. Senator Nelson of Florida is really without peer when it comes to looking after NASA's interest and making sure that the many and varied missions of NASA are functioning properly and getting the proper attention here in the Congress.

Really, Mr. Chairman, I only would have two questions for the panels when they have a chance to answer, and that would be, first, what is the safest and most economical launch vehicle for restoring NASA's capability to fly to low-Earth orbit and the International Space Station? And second is, what are NASA's plan, budget, and schedule for developing, and testing a heavy lift launch system?

I think our manned spaceflight program is at a real crossroads, and I certainly would look forward to working through this issue with the members of the Committee and with NASA.

Thank you very much.

[The prepared statement of Senator Pryor follows:]

PREPARED STATEMENT OF HON. MARK PRYOR, U.S. SENATOR FROM ARKANSAS

Chairman Rockefeller and Ranking Member Hutchison. Thank you for holding this important hearing.

NASA and the United States manned space program are at a crossroads. This Congress is being asked to make a decision that will set the course for the Space Agency for the next several decades. The choice is between continuing the Constellation Program and relying upon the private sector to develop commercial launch vehicles.

Regardless of the path America chooses, the safety of our astronauts must always be our paramount concern.

I believe this committee must find the answers to two key questions.

First, what is the safest and most economical launch vehicle for restoring NASA's capability to fly to Low-Earth Orbit and the International Space Station?

Second, what are NASA's plans, budget and schedule for developing and testing a heavy lift launch system?

I look forward to hearing today's testimony and the answers to these questions. Thank you.

The CHAIRMAN. Thank you, Senator Pryor.

And now, Dr. Holdren, I am very honored to ask you to give your testimony. You are the Director of the Office of Science and Technology Policy. You have been very helpful to me on energy matters and in many other ways. I think you are a terrific appointment.

After that, Mr. Bolden, I will introduce you.

Please.

**STATEMENT OF HON. JOHN P. HOLDREN, PH.D., DIRECTOR,
OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE
OFFICE OF THE PRESIDENT OF THE UNITED STATES**

Dr. HOLDREN. Chairman Rockefeller, Ranking Member Hutchison, members of the Committee, I certainly am happy to be here today to talk about the Administration's new strategy for human space exploration activities.

And I want to be clear at the outset. This Administration is steadfast in its commitment to space exploration and to the mission of NASA. The President and I fully recognize that space exploration plays a vital role for our Nation in advancing scientific discovery, stimulating technological innovation, enhancing our economic strength, expanding our horizons, inspiring our public and especially our kids about the potential of science and technology, and maintaining U.S. leadership internationally.

But among the several challenges that face this Administration when it came to office were the technical and budgetary difficulties of the U.S. human spaceflight program, Constellation, that we had inherited. To assess that problem, OSTP and NASA stood up the most open, transparent, and participatory Federal advisory committee activity relating to space that has ever been undertaken, the Augustine Committee to Review Human Spaceflight Plans.

As you know, the Augustine committee concluded through that process that the Constellation program had become “unexecutable” under any plausible set of assumptions about costs and budgets going forward, the victim of a mismatch between plans and available resources exacerbated by decades of underinvestment in new technology and innovation at NASA. And persisting in the pursuit of that increasingly costly program while, nonetheless, failing to meet its objectives would have the further liability of continuing to short-change NASA’s other critical activities including, as you have mentioned, robotic missions, space telescopes, Earth observation, and aeronautics. It clearly was time to push the reset button.

Accordingly, a decision-support process engaging NASA and the White House was initiated to flesh out a set of options, drawing on the Augustine committee’s findings and aiming to maximize the level of exploration and achievement attainable under realistic budgets for the President’s consideration. The result was the set of proposals for NASA’s activities and budgets rolled out as part of the President’s Fiscal Year 2011 budget request on February 1 and elaborated, as Senator Nelson has mentioned, in the President’s speech at the Kennedy Space Center on April 15.

The key elements in the Administration’s new strategy for maintaining and extending U.S. leadership in human space exploration deserve, I think, at least brief recapitulation here.

We want to extend the life of the International Space Station to at least 2020, in doing so, deriving significantly increased benefits from it in science and technology demonstration, providing a locus and focus for increased U.S. astronaut presence in space over the decade ahead, and maintaining the valuable international partnership that the International Space Station represents.

We want to catalyze the development of and then utilize commercially provided crew and cargo transportation services to the International Space Station, resulting in what we believe will be more timely and cost-effective United States capabilities for that purpose than the previous program would have provided.

We want to increase NASA’s investments in transformative technologies that can expand the reach and reduce the costs of human exploration of deep space, beginning in this way to reverse decades of under-attention to that critical need.

And we want to pursue a series of increasingly demanding human exploration missions, including a mission to an asteroid by 2025 and an orbital Mars mission in the mid-2030s, demonstrating key capabilities for a later Mars landing, while also achieving historic firsts in exploration and discovery.

I want to add a word about workforce issues. There are some near-term job losses in store, largely as a result of the retirement of the aging Space Shuttle fleet in early 2011. But that is not a new problem. The decision to retire the Shuttle in that time-frame was made in 2004 by the previous administration based, in part, on the findings of the *Columbia* Accident Investigation Board and, in part, on the need to develop less costly as well as safer technology to get our astronauts into orbit. A dilemma in the era of limited budgets is that the high cost of operating the Shuttle consumes the money that would be needed to develop its successor.

The Administration recognizes the pain and hardship of job losses in the communities affected, and we are taking a number of steps to reduce those impacts. The promotion of an expanded commercial space launch industry will create new jobs in many of the places affected by Shuttle job losses, as will the \$3 billion that will go into new R&D on heavy lift rockets in this period and additional billions in other new technologies. We think it is likely, given the additional spending in the new plan, that the magnitude of the Shuttle-related job losses will be smaller and their duration shorter under the new plan than under the old one. But they will still be real. Therefore, further steps are being taken by the Administration to mitigate those losses, including the initiative for regional economic growth and job creation along the Space Coast that the President announced on April 15.

In closing, let me say that the President and I appreciate this committee's interest in and support for the U.S. human spaceflight program and the other important missions of NASA. We are convinced that the new plan is the best way forward and optimistic that we can get it done. I look forward to working with you and others in the Congress to that end. I would be happy, of course, to respond to your questions. Thank you.

[The prepared statement of Dr. Holdren follows:]

PREPARED STATEMENT OF STATEMENT OF HON. JOHN P. HOLDREN, PH.D., DIRECTOR,
OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE
PRESIDENT OF THE UNITED STATES

Chairman Rockefeller, Ranking Member Hutchison, and members of the Committee, I am pleased to appear before you today to discuss the Administration's new strategy for U.S. human space exploration activities. I welcome the opportunity to provide additional information about these plans.

Let me be clear at the outset: This Administration is steadfast in its commitment to space exploration and to the mission of the National Aeronautics and Space Administration (NASA), as emphasized by the President in his speech at the Kennedy Space Center on April 15. Space exploration plays a vital role for our Nation in advancing scientific discovery, stimulating technological innovation, enhancing our economic strength, and promoting international leadership. And the President fully recognizes the space program's unique capacity to inspire future generations of scientists and engineers as we continue to forge new paths in pursuit of unprecedented discoveries and unimagined wonders in space.

The Obama Administration came into office facing a broad range of challenges, not least of which were the technical and budgetary difficulties of the U.S. human spaceflight program—Constellation—that we had inherited. Given the significant in-

vestments in funds and scientific capital entailed in that effort, we concluded that it was essential to obtain a fresh and objective assessment of the status of the program, as well as of the options going forward. OSTP and NASA stood up, for that purpose, an independent blue-ribbon panel, the Committee to Review U.S. Human Spaceflight Plans. Led by the distinguished aerospace engineer Norman Augustine, the Committee comprised ten experts of diverse experience—in the U.S. Government, the military, industry, and the astronaut corps—relating to the technology, management, and practice of human spaceflight. I believe the intensive review they conducted over a period of 5 months last year was the most open, transparent, and participatory Federal Advisory Committee activity relating to space ever undertaken.

The Augustine Committee's thorough and thoughtful analysis helped illuminate the range and severity of the challenges faced by the Constellation program—making clear that it had become “unexecutable” under any plausible set of assumptions about costs and budgets going forward—as well as clarifying the options for revamping U.S. human spaceflight activities so as to maximize what could be achieved under budgets that might realistically be available. Most fundamentally, the Augustine report made clear that Constellation had been plagued from the beginning by a mismatch between plans and available resources, and that it had been hindered as well by decades of underinvestment in new technology and innovation at NASA.

The report showed, more specifically, that the new rocket intended to carry U.S. astronauts to low-Earth orbit (initially to the International Space Station (ISS) and later in support of lunar missions) after retirement of the Space Shuttle in 2011, the *Ares I*, was far over budget and so far behind schedule that it wouldn't be available until after the space station had been scrapped at the end of 2015 in pursuit of savings to help pay for the rocket. The program's stated goal of returning U.S. astronauts to the surface of the Moon by 2020, moreover, using a much larger rocket (*Ares V*) and a lunar lander that were both still on the drawing board, was no longer within reach regardless of how much money might be spent on it. And under plausible NASA budgets going forward, the Constellation program could not have put U.S. astronauts back on the Moon until sometime after 2030.

In addition to scrapping the \$100 billion International Space Station before it had achieved more than a fraction of its scientific and technology-development potential, as well as suffering a six- or seven-year gap in U.S. capability to lift its own astronauts into low-Earth orbit, persisting with the pursuit of the increasingly costly Constellation program while nonetheless failing to meet its objectives would have the further liability of continuing to short-change NASA's other critical activities, including robotic missions and space telescopes, Earth observation, and aeronautics. Clearly it was time to press the reset button.

Accordingly, a decision-support process engaging NASA and the White House was initiated to home in on and flesh out a set of options for revamping NASA's human spaceflight efforts—drawing on the Augustine committee's findings and aiming to maximize the level of activity and achievement attainable under realistic budgets—for the President's consideration in connection with the preparation of his FY 2011 budget proposal. The result was the set of proposals for NASA's budgets and activities in FY 2011–2015, which were rolled out as part of the President's budget request on February 1, and further elaborated in his speech at the Kennedy Space Center on April 15.

Before turning to the ingredients of the new plan, I want to make one further important point about the old one. The President and I—and I know Administrator Bolden—are immensely grateful for the hard work and commitment shown by the men and women of NASA's government and industry workforce for the Constellation program. The mismatch of aims and resources in that program was not their fault. Nor will their efforts have been wasted—much of the knowledge and technology they have produced will be built upon in the new plan. More than that, it's our aim to put their skills and passions to work in the revamped program to the greatest extent that we can. These men and women are a national resource, and the Administration is committed to applying their expertise to a range of national challenges and needs.

The President's new strategy for maintaining and extending U.S. leadership in human space exploration has a number of important elements. Key among them are:

1. extending the life of the ISS to at least 2020, thereby deriving significantly increased benefits from it in science and technology demonstration, providing a locus and focus for increased U.S. astronaut presence in space over the decade ahead, and maintaining the valuable international partnership in space that the ISS represents;

2. catalyzing the development of, and then acquiring commercially provided crew and cargo transportation services to the ISS, resulting in what we believe will be more timely and cost-effective U.S. capabilities for this purpose than the previous program;
3. substantially increasing our investments in transformative technologies that can expand the reach and reduce the costs of human exploration of deep space, thereby beginning to reverse decades of under-attention to this critical need;
4. investing in heavy-lift propulsion R&D, which together with our technology investments will help inform a decision by no later than 2015 on the heavy lift vehicle design that we will pursue and build;
5. building a scaled-back version of the Constellation program's *Orion* crew capsule to provide crew emergency-escape services for the ISS and to provide part of the technological foundation for the advanced spacecraft to be used in future deep-space missions;
6. pursuing a series of increasingly demanding human-exploration missions to include a mission to an asteroid by 2025 and an orbital Mars mission in the mid-2030s, demonstrating key capabilities for a later Mars landing while also achieving historical firsts in exploration and discovery; and
7. ramping up robotic exploration of the solar system, including missions to "scout" the human trips to follow, as well as conducting the Earth observations necessary to improve our understanding of our climate and planetary home.

This new plan revolves around certain core strategic themes and priorities—achieving a long-needed revitalization of our technology R&D efforts, matching program goals with available resources, partnering with industry in fundamentally new and more effective ways, advancing scientific discovery, and pursuing human exploration with a more flexible, achievable, and affordable set of goals. It is designed to take us ultimately further, faster, to more places in deep space, while spurring the creation of new industries, technologies, and jobs along the way. These activities and approaches together will prove vital for the long-term sustainability of our human spaceflight activities and will help place these programs on a more stable footing for years to come.

I also would like to take this opportunity to provide additional information about certain program elements that the President highlighted on April 15 and that I touched on earlier.

The ISS and a Crew Rescue Vehicle

Under the Constellation program *Orion* was to be the crew capsule used to transport astronauts to the vicinity of the Moon before trips to the surface using the Altair lander. *Orion* was also to provide crew transportation to the ISS, where it would have docked for 6 months before returning crews to the Earth. Though the *Orion* was to fulfill the ISS mission objectives first, it was not designed primarily for that purpose. Rather, NASA initiated *Orion's* development with the objective of making it a lunar-capable spacecraft that also could meet the ISS servicing mission.

Developing an *Orion*-derived escape capsule to provide the ISS crew with assured return to Earth in case of an emergency is a less complex task than completing the *Orion* with its full suite of mission objectives, but this effort still brings important capabilities while enabling NASA to maintain critical skills in this area and continue to utilize its multi-Center, in-house team for spacecraft development. It will, as the President noted in Florida on April 15, provide "part of the technological foundation for advanced spacecraft to be used in future deep space missions."

Heavy Lift Decision

The President also directed in his speech that NASA be in a position to select a heavy-lift rocket design by no later than 2015 for its future missions beyond Earth's orbit. The President noted that "in developing this new vehicle, we will not only look at revising or modifying older models; we want to look at new designs, new materials, [and] new technologies . . ." The President's budget includes \$3.1 billion over the next 5 years in support of research for new engine technologies, new materials, and engine demonstrations or prototypes that can prove vital to a future heavy lift vehicle. Further, NASA is developing initial plans for testing and demonstrating capabilities such as in-space fuel transfer and storage, in-orbit automated and autonomous rendezvous and docking, advanced in-space electric propulsion, and others that could be important in optimizing the characteristics of a heavy lift vehicle (*i.e.*, as part of a future exploration architecture).

NASA will build and test, and in some cases fly in space, these new technologies over the next several years to assess their operational viability and collect information on their effectiveness and performance. NASA can at the same time conduct

a variety of design trade studies on potential future approaches for a heavy lift launch vehicle, and by 2015 will be able to make a decision about future heavy lift development that is informed by the combination of lessons learned from these various technology developments and associated studies. It is currently anticipated that this decision would set the general configuration of the vehicle, as well as target performance levels and other attributes. A more detailed and mature design for this vehicle likely would need to be completed following this initial decision, as part of a subsequent development effort. This timetable will enable NASA to begin building a heavy lift launch vehicle 2 years earlier than was projected under the previous plan.

Workforce Support

There are job losses in store as a result of the retirement of the aging Space Shuttle fleet in early 2011, but that is not a new problem. The decision to retire the Shuttle in this time-frame was made in 2004 by the previous Administration, based in part on the findings of the *Columbia* Accident Investigation Board and in part on the need to develop less costly as well as safer technology to get our astronauts into orbit. (A dilemma in an era of limited budgets is that the high cost of operating the Shuttle consumes the money that would be needed to develop its successor.) Several major independent reviews have affirmed that winding down the Shuttle program for these reasons is the right decision.

The Administration recognizes the pain and hardship of Shuttle job losses in the communities affected, and we are taking a number of steps to reduce these impacts. The new plan contains \$1.9 billion over the next 5 years for modernization of Florida's Kennedy Space Center and associated facilities. The promotion of an expanded commercial space-launch industry will create new jobs in many of the places affected by Shuttle job losses, as will the \$3 billion that will go into new R&D on "heavy lift" rockets in this period and additional billions in other new technologies. It's likely, given the additional spending in the new plan, that the magnitude of the Shuttle-related job losses will be smaller and their duration shorter under the new plan than under the old one. But they will still be real. Further steps the Obama Administration is taking to mitigate them include the initiative for regional economic growth and job creation along the "Space Coast" that the President announced in his April 15 speech at the Kennedy Space Center.

As the President explained on May 3, that initiative will be led by a Task Force on Space Industry Workforce and Economic Development. Co-Chaired by NASA Administrator Bolden and Secretary of Commerce Gary Locke, it will include membership from 11 other departments, agencies, and White House organizations, including my office. Its aim is to develop, in collaboration with local stakeholders, an inter-agency action plan for \$40 million in transition assistance intended to facilitate economic development strategies and plans along Florida's Space Coast, and to provide training and other opportunities for affected aerospace workers so they are equipped to contribute to new developments in America's space program, related industries, or other industries in the local area. This effort will build on and complement ongoing local and Federal economic and work force-development efforts. A plan is due to the President by August 15 of this year.

Conclusion

I appreciate this committee's interest in and support for the U.S. human spaceflight program and the other important missions of NASA. Certainly there are challenges ahead in moving forward with the revamping of these efforts that I and the other witnesses are discussing with you today. But I am convinced that it is the best way forward and optimistic that we can get it done. I look forward to continuing to work with you and others in the Congress to that end. I would be pleased to respond to questions.

The CHAIRMAN. Thank you, sir.

And now the Administrator of NASA, Mr. Charles F. Bolden, Jr., who in fact a little over 24 years ago flew with one Senator Bill Nelson. The floor is yours, sir.

STATEMENT OF HON. CHARLES F. BOLDEN, JR., ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. BOLDEN. Mr. Chairman and members of the Committee, thank you very much for the opportunity to appear today to discuss

additional information about the President's Fiscal Year 2011 budget request for NASA, following the President's important speech at the NASA Kennedy Space Center in Florida. NASA is grateful for the support and guidance received from this committee through the years and looks forward to working with you to implement the President's bold new direction for the agency.

Given that you have my detailed written statement, I will try to keep my remarks very brief this afternoon so that I have time for questions.

But first, I would like to acknowledge the incredible contributions of my two astronaut colleagues and Norm Augustine who will be on the second panel. Both Neil and Gene, the first and last humans to set foot on the Moon, have dedicated their lives to the challenging and often unforgiving pursuit of space exploration and, in doing so, have improved the quality of life in America and inspired the next generation of explorers. And they continue to contribute by remaining engaged and providing their remarks on today's important topic of the future of human spaceflight. I appreciate their thoughts and ideas, and it was very beneficial to have had the opportunity to discuss their concerns over the past 3 weeks and to present them with a thorough brief on our plans for America's future in human spaceflight and exploration in a 2-hour brief last week in an attempt to allay some of their concerns.

However, reasonable people can disagree, and so I must respectfully disagree with some of the remarks from the first panel in their prepared remarks.

The President's Fiscal Year 2011 budget request is good for NASA because it sets the agency on a sustainable path that is tightly linked to our Nation's interests. During his visit to KSC, the President articulated a strong commitment to NASA's missions and future of U.S. human spaceflight exploration.

The President also outlined an ambitious effort to foster the development of groundbreaking technologies; increase the number, scope, and pace of manned and unmanned space missions; make human spaceflight safer and more efficient; and help create thousands of new jobs. The President has laid out the goals and strategies for this new vision which includes a sequence of deep space destinations for human missions, progressing step by step, beginning with crewed flight tests early next decade of vehicles capable of supporting exploration beyond low-Earth orbit, a human mission to an asteroid by 2025, and a human mission to orbit Mars and return safely to Earth by the mid-2030s.

With respect to the role of heavy lift in the future of human spaceflight architecture, the Fiscal Year 2011 budget request includes funds for NASA to conduct the important research and development and analysis necessary to make an informed decision on a heavy lift launch vehicle no later than 2015.

On May 3, NASA issued a request for information seeking general information regarding potential launch or space transportation architectures that will be used for planning and acquisition strategy development for current heavy lift planning activities.

Regarding our plans for a restructured *Orion*, the President has directed me that NASA build on the good work already completed on the *Orion* crew capsule and focus the efforts to provide a sim-

pler and more efficient design that would provide crew emergency escape from the space station and serve as part of the technical foundation for advanced spacecraft to be used in future deep space missions. This approach also will preserve a number of critical, high-tech industry jobs in key disciplines needed for our future deep space exploration program.

We have put together a formulation team, including headquarters and center personnel, to develop a baseline approach that meets these requirements, balanced with other priorities proposed in the President's Fiscal Year 2011 budget request. This team will report to me within 3 weeks on how best to meet these requirements.

Dr. Holdren has already talked to you about the workforce initiative. So I will not cover that, but I will say that the task force, which he mentioned which I co-chair with Secretary of Commerce Locke, will also explore future workforce and economic development activities that could be undertaken for affected aerospace communities in other states as appropriate, and we held the first meeting of that task force this morning.

NASA expects to submit a revised Fiscal Year 2011 budget request to Congress in the near future that will identify funding requirements for the restructured *Orion* crew capsule, as well as funding requirements for the workforce transition.

Finally, regarding the International Space Station's role in furthering research, technology, and innovation, this orbiting national lab represents a unique research capability which the United States and its partner nations can use to conduct a wide variety of research in biology, chemistry, physics, and engineering fields that will help us better understand how to keep astronauts healthy and productive on long-duration space missions. ISS can and will play a key role in the technology demonstrations and engineering research associated with exploration.

Mr. Chairman, in conclusion, Americans and people worldwide have turned to NASA for inspiration throughout our history. Our work gives people an opportunity to imagine what is barely possible, and we at NASA get to turn those dreams into real achievements for all humankind. This budget gives NASA a road map to even more historic achievements as it spurs innovation, employs Americans in fulfilling jobs, and engages people around the world as we enter an exciting new era in space.

I thank you again, Mr. Chairman, for your support and that of this committee. I would be pleased to respond to any questions you or other members of the Committee may have.

[The prepared statement of Mr. Bolden follows:]

PREPARED STATEMENT OF HON. CHARLES F. BOLDEN, JR., ADMINISTRATOR,
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and members of the Committee, thank you for the opportunity to appear today to discuss additional information about the President's FY 2011 budget request for NASA, following the President's important speech at the NASA Kennedy Space Center (KSC) in Florida. NASA is grateful for the support and guidance received from this committee through the years and looks forward to working with you to implement the President's bold new direction for the Agency.

The President's FY 2011 budget request is good for NASA because it sets the Agency on a sustainable path that is tightly linked to our Nation's interests. The President recognizes that what is truly needed for beyond low-Earth orbit (LEO) ex-

ploration are game-changing technologies; making the fundamental investments that will provide the foundation for the next half-century of American leadership in space exploration. In doing so, the President has put forward what I believe to be the most authentically visionary policy for human space exploration that we have had since President Kennedy challenged NASA to send humans to the Moon and return them safely back to Earth. At the same time, under the new plan, we will ensure continuous American presence in space on the International Space Station (ISS) throughout this entire decade and likely beyond, re-establish a robust and competitive American launch industry, launch more robotic probes into our solar system as precursors for human activity, invest in a new heavy lift research and development (R&D) program, and build a technological foundation for sustainable, beyond-LEO exploration, with more capable expeditions in lunar space, and human missions to near-Earth asteroids, the Moon, Lagrange points, and, ultimately, Mars. NASA will embark on these transformative initiatives by partnering with the best in industry, academia and other government agencies, as well as with our international partners.

At the request of the Committee, today I will provide additional details about pending revisions to the President's FY 2011 budget request for NASA. I will discuss NASA's progress in developing plans for the new exploration initiatives included in the FY 2011 budget request, including initial planned program assignments for major programs by Center. Additionally, my testimony will provide additional detail about three significant updates that were announced by the President when he visited KSC on April 15, 2010. NASA is working expeditiously to provide specific budgetary details to reflect these updates and we will share them with this Committee and other Congressional stakeholders as soon as we are able.

President Obama Visits KSC

During his visit to KSC, the President articulated a strong commitment to NASA's mission and future U.S. human space exploration. The President also outlined an ambitious effort to foster the development of ground-breaking technologies; increase the number, scope, and pace of manned and unmanned space missions; make human spaceflight safer and more efficient; and help create thousands of new jobs. The President directed that NASA proceed to develop a crew rescue vehicle based on the *Orion* space-capsule to support emergency crew return requirements on the ISS, and providing a technological foundation for systems that can later take us beyond Earth's orbit. In addition to investing in transformative heavy-lift technologies, the President has called on NASA to select a basic rocket design, no later than 2015, and then begin to build it. The President also said that after decades of neglect, we will increase investment—right away—in other groundbreaking technologies that will allow astronauts to reach space sooner and more often, to travel farther and faster for less cost, and to live and work in space for longer periods of time more safely. And, the President laid out the goals and strategies in this new vision for NASA. Fundamentally, the exploration of space will be a sequence of deep-space destinations for human missions matched to growing capabilities, progressing step-by-step, beginning with crewed flight tests—perhaps a circumlunar mission—early next decade of vehicles capable of supporting exploration beyond LEO, a human mission to an asteroid by 2025, and a human mission to orbit Mars and return safely to Earth by the 2030s. Finally, the President committed to providing \$40 million for workforce transition initiatives to aid Florida's Space Coast.

NASA expects to submit a revised FY 2011 budget request to the Congress in the near future that will identify funding requirements for the restructured *Orion* crew capsule as well as funding requirements and authorization for workforce transition for Florida and potentially other locations.

Restructuring the Orion Crew Capsule

Per the President's direction, we are going to build on the good work already completed on the *Orion* crew capsule and focus the effort to provide a simpler and more efficient design that would provide crew emergency escape from the ISS and serve as part of the technical foundation for advanced spacecraft to be used in future deep space missions. This approach also will preserve a number of critical high-tech industry jobs in key disciplines needed for our future deep space exploration program.

We have put together a formulation team including Headquarters and Center personnel to develop a baseline approach that meets these requirements, balanced with the other priorities proposed in the President's FY 2011 budget request. This team will report to me within 3 weeks on how best to meet these requirements.

I have directed the team to align this work so that it complements, and does not compete with, our commercial crew development effort. In this manner, we will simplify the requirements for potential crew service providers to the ISS by having the

restructured *Orion* effort fulfill the important safety requirement of emergency escape system for astronauts on the ISS. I have also directed the formulation team to focus on innovative approaches to oversight, and believe that we can significantly reduce oversight requirements based on lessons learned in previous focused development flight programs. We must accomplish this activity more efficiently and effectively to maintain a healthy funding balance across our exploration priorities. And this will be done without reducing our commitment to safety for crew escape. The crew rescue mission has many fewer requirements than the deep space mission, providing design flexibility and reducing the system's lifecycle cost. Finally, the team must identify how this activity will align with the development efforts proposed in the Flagship Demonstration program as well as our other technology efforts so that investments in these programs can be leveraged to the greatest extent possible.

The funding for this restructuring will come within NASA's top-line request released in February. The out year funding requirements will be refined as part of the President's FY 2012 budget submission.

Heavy-Lift Technologies

During his visit to KSC, the President specifically recognized the need for a heavy-lift launch capability to carry humans beyond LEO by requiring a decision on a vehicle design no later than 2015. Such a decision would include setting performance goals, identifying lift capability and selecting the general vehicle design—work that will ultimately lay the path for launching a spacecraft for crewed missions into deep space.

The FY 2011 budget request includes funds for NASA to conduct the important R&D and analysis necessary to make an informed decision on a heavy-lift vehicle no later than 2015. This effort will primarily focus on the development of a U.S. first-stage hydrocarbon engine for potential use in future heavy lift (and other) launch systems, as well as basic research in areas such as new propellants, advanced propulsion materials manufacturing techniques, combustion processes, propellant storage and control, and engine health monitoring. Additionally, NASA will initiate development and testing of in-space engines. Areas of focus could include a liquid oxygen/methane engine and low-cost liquid oxygen/liquid hydrogen engines. This work will build on NASA's recent R&D experience in this area, and the test articles will be viewed as a potential prototype for a subsequent operational engine that would be re-startable and capable of high acceleration and reliability. These technologies will increase our heavy-lift and other space propulsion capabilities and significantly lower operations costs—with the clear goal of taking us farther and faster into space consistent with safety and mission success criteria. In support of this initiative, NASA will explore cooperative efforts with the Department of Defense and also develop a competitive process for allocating a small portion of these funds to universities and other non-governmental organizations. This research effort along with many of our new technology initiatives will be coordinated with the broader Agency technology initiative led by NASA's new Chief Technologist.

On May 3, 2010, NASA issued a Request for Information (RFI) seeking general information regarding potential launch or space transportation architectures (expendable, reusable, or a hybrid system) that could be utilized by multiple customers (*e.g.*, NASA, commercial and other Government agencies). The RFI solicits information regarding propulsion system characteristics; technology challenges related to liquid chemical propulsion systems; as well as innovative methods to manage a heavy-lift development program to include effective and affordable business practices. The RFI is open to the broad space community, including commercial, other Government agencies and academia. Information obtained from the RFI will be used for planning and acquisition-strategy development for current heavy-lift planning activities, funded at a total of \$100 million in the FY 2010 Consolidated Appropriations Act (P.L. 111–117).

Assistance for the Florida Space Coast

The men and women who work in the Space Coast's aerospace industry are some of the most talented and highly trained in the Nation. It is critical that their skills are tapped as we transform and grow the country's space exploration efforts. The 2004 decision to end the Shuttle means that approximately 6,000 jobs need to be transitioned into the new space strategy and related industries. Recognizing the concerns of our dedicated Shuttle workforce as they conclude this remarkable program and look forward to transitioning to new work, the President has announced a \$40 million initiative to develop a plan for regional economic growth and job creation for the Florida Space Coast. On May 3, 2010, the President issued a Memorandum directing the establishment of the Task Force on Space Industry Workforce and Economic Development. The task force is charged with developing, in collabora-

tion with local stakeholders, an interagency action plan to facilitate economic development strategies and plans along the Space Coast and to provide training and other opportunities for affected aerospace workers so they are equipped to contribute to new developments in America's space program and related industries. They will also explore future workforce and economic development activities that could be undertaken for affected aerospace communities in other States, as appropriate. The Secretary of Commerce and I will serve as Co-Chairs. Other team members will include: the Secretary of Defense; the Secretary of Labor; the Secretary of Housing and Urban Development; the Secretary of Transportation; the Secretary of Education, the Chair of the Council of Economic Advisors; the Director of the Office of Management and Budget; the Administrator of the Small Business Administration; the Director of National Intelligence; the Director of the Office of Science and Technology Policy; the Director of the National Economic Council; and the heads of other Executive agencies, as needed. As directed, the team will report its recommendations to the President by August 15. The \$40 million for this initiative will be taken from the funds requested for Constellation transition in the original FY 2011 Presidential budget request.

This interagency group's recommendations will build on the Administration's ongoing efforts in the KSC region. The Department of Labor is already planning a pilot program to better assist the region's workers, including those highly-skilled workers who work in the aerospace industry, through efforts to establish one-stop local transition centers for affected workers where they can receive coordinated local, state, and Federal workforce assistance tied to economic development efforts; and the designation of a single Federal point-of-contact for affected areas.

To further facilitate these efforts, the Department of Commerce's Economic Development Administration (EDA) is prepared to support a comprehensive economic adjustment strategy for the Kennedy Space Center economic region. With funding provided through NASA, the EDA will provide both financial and technical assistance to start implementing those plans and promote economic development in the region through such activities as infrastructure upgrades and improvements, entrepreneurial networks, and skill- training facilities and equipment. The exact mix of activities will depend on the recommendations and request of local entities across the region.

In addition, on April 30, 2010, the Department of Labor announced a \$1.2 million grant to assist approximately 200 workers affected by layoffs at ATK Launch systems in Corinne, Utah, in connection with the transition of the Space Shuttle and Constellation programs.

NASA Prepares to Implement the FY 2011 Budget Request

Pursuant to the President's proposed new course, NASA has initiated planning activities to be able to effectively and efficiently implement these new activities in a timely manner upon Congressional enactment of the FY 2011 budget. In April, NASA outlined for the Committee the Agency's planned major program assignments across the Agency's Centers for new or extended activities proposed as part of the President's FY 2011 budget request. These planned assignments build on the deep knowledge and expertise that NASA has built up over five decades, recognize the wealth of experience, commitment, and expertise resident at the NASA Centers, and expand upon the strengths at each Center.

I wish to emphasize that establishment of program offices and initiation of effort in support of new or extended activities for this proposed new work is contingent upon Congressional approval of the President's FY 2011 request for these activities. These planned program assignments will enable NASA to engage workforce at the Agency's Centers in formulation activities for the array of program initiatives in Science, Aeronautics, Space Technology, Exploration, and Space Operations reflected in the President's FY 2011 request. While we will be developing details on the specific numbers of employees at our Centers that will be assigned to new program offices and activities, these planned assignments are intended to provide the Committee additional detail regarding the depth and scope of the President's FY 2011 proposed budget plan.

Planned major program assignments for elements contained in the FY 2011 budget, by Center, follow:

- Johnson Space Center, Texas
 - Exploration/Flagship Technology Demonstrations, Manager
 - Exploration/Commercial Crew Development, Deputy Program Manager
 - Exploration/Commercial Cargo Development, Manager
 - Exploration/Human Research, Manager

- ISS, Manager
- Kennedy Space Center, Florida
 - Exploration/Commercial Crew Development, Manager
 - Space Operations/21st Century Launch Complex, Manager
 - Exploration/Flagship Technology Demonstrations, Deputy Program Manager
 - Space Shuttle/Completion of Manifest, Manager
- Marshall Space Flight Center, Alabama
 - Exploration/Heavy Lift and Propulsion R&D, Manager
 - Exploration/Robotic Precursor Program, Manager
 - Space Technology/Crosscutting Capability Demonstrations/Technology Demonstration Missions, Manager
 - Space Technology/Centennial Challenges Program, Manager
- Stennis Space Center, Mississippi
 - Exploration/Heavy Lift and Propulsion R&D, First Stage and Upper Stage Rocket Testing
 - Exploration/Commercial Crew Development, Engine Testing for Commercial Vehicles
- Glenn Research Center, Ohio
 - Exploration/Exploration Technology Development and Demonstration, Manager
 - Space Technology/Early Stage Innovation/Research Grants
 - Aeronautics Research/Integrated Systems Research Program, support
- Langley Research Center, Virginia
 - Space Technology/Game Changing Technology/Game Changing Development, Manager
 - Climate Initiative: SAGE III; CLARREO (managed jointly with Goddard); Venture Class
 - Aeronautics Research/Integrated Systems Research Program and Airspace Systems Program, support
- Dryden Flight Research Center, California
 - Space Technology/Crosscutting Capability Demonstrations/Flight Opportunities, Manager
 - Aeronautics Research/Integrated Systems Research Program and Airspace Systems Program, support
- Ames Research Center, California
 - Exploration/Precursor Robotic Missions/Exploration Scouts, Manager
 - Space Technology/Game Changing Technology/Small Satellite Subsystem Technologies, Manager
 - Space Technology/Crosscutting Capability Demonstrations/Edison Small Satellite Demonstrations, Manager
 - Aeronautics Research/Integrated Systems Research Program and Airspace Systems Program, support
- Goddard Space Flight Center, Maryland
 - Joint Polar Satellite System (restructuring NPOESS), procurement structure modeled after past successful programs
 - Climate Initiative: ICESat-2; CLARREO (managed jointly with Langley); DESDynI (managed jointly with Jet Propulsion Laboratory); Earth Systematic Missions Program
- Jet Propulsion Laboratory, California
 - Climate Initiative: SMAP; DESDynI (managed jointly with Goddard); GRACE, OCO-2

Following the release of the FY 2011 budget request, NASA established study teams within the Exploration Systems Mission Directorate (ESMD) to ensure we understand the steps (and the implications of those steps) that would need to be taken

for an orderly transition of the Constellation Program and to plan for the implementation of the new initiatives in the Exploration program. The work undertaken by these teams is a necessary part of that planning. Following is a brief summary of the additional details developed for each initiative, as “point of departure” plans to support FY 2011 budget implementation, once the budget is approved. Please note these are preliminary ESMD plans that may need to be modified following finalization of Agency plans regarding the restructuring of the *Orion* crew capsule.

- *Flagship Technology Demonstrations*: The next generation of capabilities key to sustainably exploring deep space will be demonstrated through four proposed missions: advanced space propulsion in 2014, in-space propellant and fuel transfer in 2015, light weight/inflatable modules in 2016, and aero-assist in 2017. Autonomous operations and advanced life support capabilities will also be tested on these missions. Detailed definition of each mission’s content is currently under way.
- *Heavy Lift and Propulsion Technology*: Planned technology investments will lead to a demonstration of an in-space engine in 2015, development of a first stage propulsion system by 2020, and maturing other foundational propulsion technologies to support a heavy lift vehicle decision in the 2015 timeframe. NASA’s efforts will be primarily focused on a LOX/RP first stage and either a LOX/methane or LOX/hydrogen in-space engine. Additional research will be dedicated to analysis and trades regarding fuel types, performance requirements, and vehicle architectures.
- *Exploration Robotic Precursors*: A series of annual exploration robotic precursor missions is being planned, beginning with launch of a Near-Earth-Orbit (NEO) mission in 2014, followed by a lunar lander in 2015, and two Mars missions in 2016 and 2018, respectively. In addition, smaller robotic scout missions will be launched every 12–18 months to support reconnaissance, evaluate hazards, and develop systems and operations in support of future human exploration.
- *Enabling Technology Development and Demonstration*: Enabling technology will advance fundamental technologies in 10 portfolio areas that will lead to ground and flight demonstrations in lunar volatiles, high power electric propulsion, autonomous precision landing, human exploration tele-robotics, fission power systems, and other areas. The flight demonstrations will be done as part of flagship demonstrations, robotic precursor missions, or utilizing the ISS, ground tests and analogs.
- *Human Research*: Through research and technology development, the goal of the Human Research Program is to reduce the highest risks to crew health and performance for space exploration missions. Increased investments will be made in the fields of biomedical technology, space radiation research, and behavioral health research. There are also plans to make increased use of the ISS facilities.
- *Commercial Crew*: NASA is continuing to define plans to expedite and improve the robustness of ISS crew and cargo delivery. In addition, NASA is developing a plan that supports the development of commercial crew transportation providers to whom NASA could competitively award crew transportation services. Solicitations for commercial crew transportation development will provide opportunities for both established and traditional aerospace companies as well as emerging entrepreneurial companies. Related to this activity, this summer, NASA plans to release a Request for Information to seek industry feedback on our human rating requirements.
- *Constellation Transition*: The team is leveraging expertise from across the Agency to develop a rapid and cost effective ramp-down plan that will free the resources required for new programs. As part of the early characterization and integrated planning effort, this team has initiated a broad survey of current work force, contracts, facilities, property, security, knowledge capture, information technology, and other government agency interface issues to determine what infrastructure and hardware could be used by the new programs and projects. The transition plan will outline three phases as part of an action plan for initial deliverables: Near-term actions, transitioning of Constellation elements, and transition of assets/resources to new Exploration focus areas and other NASA programs, where appropriate.

NASA is taking prudent steps to plan for the new initiatives included in the FY 2011 budget request, including Requests for Information (RFI), workshops, and preliminary studies. NASA is eager to receive external input from industry, academia, and other partners, and is accomplishing this via a series of RFIs and industry workshops conducted this spring and into the summer. Doing so will ensure that

NASA receives important feedback from our space partners before it begins to finalize its implementation plans for the new technology demonstrations and human spaceflight systems development activities that will be supported by the FY 2011 budget, once approved by Congress. During CY 2010, NASA plans to issue a series of program formulation documents seeking input from the broader space community. The following are tentative timeframes for these activities:

- *Flagship Technology Demonstrations*: RFI in May/June.
- *Heavy Lift and Propulsion Technology*: RFI issued May 3, 2010; Broad Agency Announcement (BAA) in May/June.
- *Exploration Robotic Precursor Missions*: RFI in May/June.
- *Enabling Technology Development*: RFI issued May 7, 2010; BAA in June/July.
- *Human Research Program*: BAA in July

The first major public discussions about NASA's FY 2011 planned activities will occur at a two-day Exploration Enterprise Workshop scheduled for May 25–26 in Galveston, Texas. The workshop will bring together a broad community of stakeholders from industry, academia, and the Federal Government to engage in discussions related to strategy building, development, and the implementation of the new plans for human and robotic exploration in space.

The workshop will focus on the President's FY11 budget request for NASA Exploration. The Agency has completed the initial phase of planning for the new technology and robotic programs and will provide insight into progress to date. The objectives of the workshop are to:

- Describe and discuss the activities planned for inclusion in the new programs.
- Discuss NASA Center proposed Program assignments.
- Solicit feedback, ideas and suggestions from interested parties.
- Prepare for the next steps once the new programs are implemented.

In addition, NASA has also established study teams to plan for the implementation of the new initiatives related to the ISS Augmentation, 21st Century Space Complex and Space Technology. Additional information on these planning efforts as well as planned RFIs, workshops, and preliminary studies are outlined below.

- *ISS Augmentation*: The ISS program is reviewing functionality enhancements that will make the space station more capable and efficient, including: upgraded environmental systems and communications, techniques for saving space and improving the use of pressurized volume, tools for optimizing flight- and ground-crew time, upgrading and expanding payload operations, enhancing EVA and robotics use on Station, and reducing the complexity of international interfaces.
 - NASA will initiate an independent organization, as recommended by the Augustine Committee and the National Research Council that will support the space station research community.
- *21st Century Space Launch Complex*: NASA has developed a list of potential project ideas with preliminary estimates to be used as one potential source of solutions to customer needs as they are identified. These initial focus areas will be adjusted as customer needs are better understood: (1) Expanding capabilities to support commercial launch providers; (2) Environmental remediation; (3) Enhancing payload processing capabilities; and, (4) Supporting the modernization of the launch range capabilities.
 - This month, NASA will release an RFI to get a first-hand understanding of investments that would be most useful in support of launch and related activities in order to help the Agency prioritize near-term projects.
- *Space Technology*: NASA's Space Technology initiative under the Office of the Chief Technologist (OCT) will develop and demonstrate advanced space systems concepts and technologies enabling new approaches to enhance NASA's current mission set and enable future missions. Planning teams continue to make significant progress: an internal technology governance plan has been approved; an Agency-level technology road mapping activity is planned to begin in July; and, approved technology program plans for Early Stage Innovation, Game Changing Technology, and Crosscutting Capability Demonstrations will be completed by the end of June.
 - NASA will issue a Crosscutting Capability Demonstrations RFI in late May 2010. Game Changing Technology Industry Day will occur in late June 2010.

Early Stage Innovation NASA Research Announcements (NRA's) are targeted for late June 2010. An RFI soliciting potential topics for the proposed Space Technology Graduate Fellowship program has been released to the NASA Centers and Federal Research Laboratories.

Finally, NASA has established the Human Exploration Framework Team (HEFT) to serve as a cross-Agency planning activity. The team is being led by the Exploration Systems Mission Directorate and staffed with technical leaders from across NASA Centers. The team is focused on developing and reviewing the integrated set of requirements and technologies required for future human spaceflight missions to many destinations, including Mars. As part of its broad integration charter, HEFT will develop implementation recommendations on the performance and pacing requirements for the technologies needed for future human exploration missions using "design reference missions," or DRMs. These DRMs will be the basis for validating capabilities and missions for 5, 10-, and 15-year horizons, with milestones including crewed missions beyond the Moon into deep space by 2025, sending astronauts to an asteroid, and eventually landing on Mars. NASA expects to have initial products from the HEFT team this summer.

Extension and Enhanced Use of the International Space Station

A key element of America's future in space is the ISS that is due to be completed this year. As of May 2009, the ISS is able to support a six-person permanent crew. The three major science labs aboard ISS were completed in 2009 with the delivery of the Exposed Facility of the Japanese Kibo module. The ISS represents a unique research capability which the United States and its partner nations can use to conduct a wide variety of research in biology, chemistry, physics and engineering fields that will help us better understand how to keep astronauts healthy and productive on long-duration space missions. If Congress approves the FY 2011 budget request, NASA will be able to fully utilize the ISS and increase its capabilities through upgrades to both ground support and onboard systems. Importantly, this budget extends operations of the ISS, likely to 2020 or beyond.

ISS research is anticipated to have terrestrial applications in areas such as biotechnology, bioengineering, medicine and therapeutic treatment. The FY 2011 budget request for ISS reflects increased funding to support the ISS as a National Laboratory in which this latter type of research can be conducted. NASA has two MOUs with other U.S. Government agencies, and five agreements with non-government organizations to conduct research aboard the ISS. NASA intends to continue to expand the community of National Laboratory users of the ISS.

ISS can also play a key role in the technology demonstrations and engineering research associated with exploration. Propellant storage and transfer, life support systems, and inflatable technology can all benefit by using the unique research capabilities of ISS. In addition to supporting a variety of research and development efforts, the ISS will serve as an incubator for the growth of the low-Earth orbit space economy.

As a tool for expanding knowledge of the world around us; advancing technology; serving as an impetus for the development of the commercial space sector; demonstrating the feasibility of a complex, long-term, international effort; providing critical data regarding human long-duration spaceflight; and, perhaps most importantly, inspiring the next generation to pursue careers in science, technology, engineering, and mathematics, the ISS is without equal.

Conclusion

Americans and people worldwide have turned to NASA for inspiration throughout our history—our work gives people an opportunity to imagine what is barely possible, and we at NASA get to turn those dreams into real achievements for all humankind. This budget gives NASA a roadmap to even more historic achievements as it spurs innovation, employs Americans in fulfilling jobs, and engages people around the world as we enter an exciting new era in space. NASA looks forward to working with the Committee on implementation of the FY 2011 budget request.

Chairman Rockefeller, thank you for your support and that of this committee. I would be pleased to respond to any questions you or the other members of the Committee may have.

The CHAIRMAN. Thank you very much, Administrator Bolden.

I will start the questions and I will ask one which I hope each of you will answer.

A variety of priorities have been suggested, and I suggested in my opening statement what we did by definition does not have to

be what we always continue to do. I did, however, heavily mention human spaceflight.

But, Dr. Holdren, starting with you and then to you, Mr. Administrator, how would you list, if you are looking at the future, the budget requirements and the needs of the Nation and the world, the priorities of NASA?

Dr. HOLDREN. Well, Mr. Chairman, as I have already indicated, I think NASA has a number of important responsibilities, important areas of activity, and we really have to figure out, within the constraints of a limited budget, how to advance all of the most important ones.

Clearly, human space exploration is an important element for the reasons I mentioned at the beginning of my testimony and for others we could elaborate. It has been and will continue to be an immense inspiration to every new generation of American young people, bringing more of them into science, math, and engineering, strengthening our economy, enabling us to address a wide variety of other issues, and it is very important to the most fundamental of human drives, which is to understand and explore the universe around us.

At the same time, we have to maintain the Earth observation activities of NASA. We have to maintain the aeronautics activities of NASA, including its contributions to a next-generation air traffic control system to green aviation and much more. We have to maintain the contributions of NASA to the non-human exploration in the sense of space telescopes, in the sense of robotic missions. It really is not possible to say we can dispense with any of these, and I believe that under the President's plan we can, indeed, nurture all of them in ways that will move us forward as a society.

The CHAIRMAN. If I am talking about medical and scientific and other kinds of research, those would fall somewhere below?

Dr. HOLDREN. No, no. Absolutely not. I am talking about research. We need to do more research in understanding our place in the universe. We need to do more fundamental science using the capabilities of NASA. We need to use the capabilities of NASA to do more advanced technology development, some of which will be useful directly in the exploration program and much of which will spin off into immensely valuable economic contributions across our society. What I am saying, sir, is we need to maintain all of those major functions of NASA, and I am saying that we believe we can do it with the budget that the President has proposed for Fiscal Year '11 and going forward.

The CHAIRMAN. Thank you.

Mr. BOLDEN. Mr. Chairman, ironically I woke up early this morning and I went online and I listened to the White House tapes from November 21, 1962, and it was a heated discussion between President John Kennedy and NASA Administrator James Webb who, by the way, was a Marine and a pilot. I did not know that until this morning. But the discussion was about the question you just asked. And President Kennedy asked Administrator Webb is lunar landing the top priority for NASA, and Administrator Webb said no. It is science. It is technology development. And for quite some time, they went back and forth arguing about it.

It is easy for me to answer your question. The top priority for NASA in my estimation is human spaceflight development and pushing us beyond the bonds of low-Earth orbit. Everything else is second and it is only through the execution of human spaceflight that we can open up the avenues making it available for us to do research and development. It is the desire to go to places like Mars that will draw on people, companies around the country, academia, if we can get them the money, to develop the capabilities that will allow us to go places like that.

Short of wanting to send humans beyond the bounds of low-Earth orbit, we have a number of other Federal agencies that can do my job. So that is a personal—you asked me a personal question. I gave you a personal opinion.

The CHAIRMAN. And I appreciate it and I thank you.

Senator HUTCHISON?

Senator HUTCHISON. Well, thank you, Mr. Chairman.

I have listened to both of you and you have focused on the science and going beyond low-Earth orbit as the priorities, and I agree with you. In fact, General Bolden, in your testimony, you talk about the use of the space station, but you talk about what we can learn to make it healthier and better for astronauts and others to go into space, which I think is important.

But there is also the vast field of medical technology that we have already gained immensely from space exploration, and there is more that is going on right now. NASA and NIH, as you know, have a memorandum of understanding. NIH is looking at the treatment of causes of cancer, the diagnosis of heart, blood, vessel, lung, and blood diseases, cell and organism aging, reducing the burden of arthritis, and the development of new biomedical imaging, things that can only be done in the microgravity conditions.

The space station is such a key component of the research that, Dr. Holdren, you are championing and I know, General Bolden, you also say is part of your focus. Yet, we cannot have a space station that will be productive, that will be stable, that we can be sure will fulfill the hundred billion dollar investment that has already been made in that vehicle without assurance that we can get people up there, that we can have the cargo that might be needed in the later years because it has been extended.

So I come back to the question of, if you do not look at the stable source of getting people there, how can you say the mission and goal of science and productivity is going to be achieved? That is my concern. If the *Soyuz* is out of pocket or if they raise their rates because they are the only means that we have so that it is so prohibitive, we could be spending the same money on our own capabilities and learn from that much more than just renting space on the *Soyuz*. Or if we have some blowup in the commercial companies that are not able to fulfill their contract, they are untested—you are putting all of our dreams and hopes and taxpayer dollars into this commercial investment.

What are you going to do if there are overruns, which there already are? Are you intending to have the taxpayers then have no choice but to go forward and spend more money? Why not continue doing it in a tried and true, proven, 50-year recorded entity, which is NASA? Why have you gone on this tack where you are putting

so much emphasis on untested sources to assure that the space station will be utilized to its full potential?

Mr. BOLDEN. Senator, if I may say, there is only one untested source, and it is not really untested. Of the two competitors right now in the COTS program, it is SpaceX. Orbital is a very successful space company. They have flown Pegasus and a number of other spacecraft for many years. They have flown payloads to orbit. They know what they are doing. Orbital was the subprime on the Launch Abort system that we just had an incredible success on out at White Sands. So if I want to say why do I have confidence in them, I have confidence in them because they have demonstrated their ability to put things in space.

When you talk about exploration and research on the International Space Station, I could not agree with you more. I am very confident and comfortable, however, with my partners, the Russians, because they have the best record of safety and reliability in terms of access to space. They have now flown, I think, 90 missions without an accident or loss of life. There is no other person, there is no other source of access to low-Earth orbit that can match that record.

And the last thing I will say is as good as Energia is and Roscosmos, I defy anyone who says that American industry is not as good or better than they are. So I have to be confident that Orbital, SpaceX, McDonnell Douglas—not even around anymore—Boeing, the other American manufacturers can match, if not exceed, that of Energia. I am confident that American industry is better than Russian industry. And I am happy with what the Russians do.

Dr. HOLDREN. Could I add one—

Senator HUTCHISON. I could not agree more. Go ahead.

Dr. HOLDREN. The one comment I wanted to add to that is just to remind folks that all of the rockets and all of the spacecraft that we have been using from the beginning of the space era have been built by the private sector. What we are talking about is changing the acquisition model.

Senator HUTCHISON. But here is the key. It is what I was going to say. It is not that we will not rely on private contractors. Of course, we will. But it will be under the auspices and control of NASA and their tried and true 50 years of experience, not giving them \$6 billion, which is what is in the President's proposal, and just saying, you go do this, without all of the other aspects, the training, the testing, and the mission control. There is so much more than just building the rocket or building half of the *Orion*. It has to all fit together.

What my concern is, is that you are terminating the Constellation. In your budget you have \$2.5 billion to terminate. That is the termination, and there are reports all over the place that you are terminating contracts or that you are making it essential that they self-terminate. For \$2.5 billion, we could have another Space Shuttle. We could spread out the Space Shuttle for that over a year. You could have two in a year. So I am just concerned about the priorities and the control.

And I am way over time, and I appreciate it, Mr. Chairman. I know we will have a lot of time to discuss this. Thank you.

The CHAIRMAN. Do you want to respond?

Dr. HOLDREN. I am going to make one statement that Administrator Bolden is probably too modest to make. Safety will remain under the oversight of NASA. This gentleman on my left was in charge of safety for the astronaut corps when he was an astronaut. He knows how important that is. While Charlie Bolden is Administrator of NASA, there is going to be no shortfall in the oversight of the private sector in delivering astronauts to Earth orbit in terms of safety. I just wanted to make that one point because it has come up from time to time.

Senator HUTCHISON. Mr. Chairman, let me just make one quick point. I am not against the private sector. I am just against the private sector being the only source of this mission.

The CHAIRMAN. Senator Nelson?

Senator NELSON. And, Senator Hutchison, I think that is a good point. Space is a very unforgiving kind of environment, and NASA has always run the programs being built by contractors, not contractors running the programs with oversight of NASA. Now, that is a new way of doing business, Dr. Holdren.

Dr. HOLDREN. Yes.

Senator NELSON. Needless to say, there are some people who question the wisdom of that, but the fact is that if it does not work or if it gets extended way out, then we do not have a backup system, save for our partners, the Russians. But they have a limited capability of getting stuff up and back with the size of the *Soyuz*.

I want to get into the normal decisionmaking process because normally what happens is NASA sends to the Office of Management and Budget by November their budget, their suggested budget. Normally OMB then sends their iterations back to NASA for NASA's commentary. But that did not happen this year. Instead, the pass-back from OMB came right at the time of the announcement of the President. And as you know, the President had to go down to the Kennedy Space Center and change some things because of the mistakes that were made in the rollout which unfairly characterized the President as an opponent of human spaceflight, of which this Senator knows him to be an avid proponent.

So, Dr. Holdren, I want to ask you, when OMB came back, did OMB consult you in the final determinations of the NASA budget? When I say you, I am talking about your organization.

Dr. HOLDREN. The answer to that in brief is yes, absolutely, but let me answer the question in a little more detail.

As you know, Senator Nelson, this was not an ordinary year. It was a year in which a determination was made after receipt of the Augustine report that really fundamental changes in the priorities and the structure of NASA's human spaceflight program going forward were going to be necessary. And of necessity, the process of figuring out what those would be had to be integrated with the Fiscal Year 2011 budget process, and that is the way it was done.

There have been a number of suggestions, including one that we heard in one of the opening statements, that neither I nor the NASA Administrator was involved in this process. I can assure you that the President's decision in this matter was not hasty and it was not lacking in input from a wide range of well-informed advisors. Those included me—

Senator NELSON. Let me interrupt you because I am down on limited time here.

Dr. Holdren, when did the NASA Administrator—when was he consulted in the period of time, 2 weeks, before the rollout of the budget?

Dr. HOLDREN. Senator, I do not want to get into the internal pre-decisional deliberations and how they took place in detail. You and I both know that I cannot do that.

Senator NELSON. OK, but let me ask you this. Let me ask you this. Were any of the center directors in NASA consulted?

Mr. BOLDEN. Senator Nelson, may I answer the question, if it is possible? Because I think I know the answer better than Dr. Holdren in this particular case. Beginning in—I became the NASA Administrator in July. Beginning in August—and there is a very smart young man who is sitting behind you on your right who was my brain, my strategic brain, by the name of Tom Cremins, and he will tell you that beginning in August, we had a periodic series of strategic planning meetings among the senior leadership in NASA, which included the center directors, the associate administrators, and every senior leader in NASA. And this went on for a number of months.

And during that period of time, because I am a Marine and I flew the Space Shuttle where you know we do disaster training, we discussed every potential outcome of the budget. And I spent probably a month where I asked everybody to look at the worst case scenario which was, you know, what happens if everything goes away and we get nothing and we have to start from scratch. We knew that would not be good, but we determined that we in NASA, because we know how to do things, could recover from that.

So center directors, associate administrators, and senior leadership of NASA has been involved in the deliberations that led to our submission of our budget proposal since August.

As Dr. Holdren has said, because the results from the Augustine committee were delayed from when we thought they would come, then we all found ourselves very late in the process in doing things. And as I have said to most of you when I have come to talk to you, I accept the blame. I am 6 months behind, conservatively, where I would have been in a normal budget process. We would have had discussions with members and their staffs back in the fall. We could not do that because Augustine came out and we went back to the drawing board again and continued to discuss.

I provided lots of input to the President over a period of time. As I have said before, it is my budget. It is my plan, and I am here to defend it because I think it is the right thing for us to do.

Dr. HOLDREN. I would like to say one more word to finish my answer, if I may, with your permission.

The President heard from a lot of people in this process. He heard from me. He heard from Administrator Bolden. Senator Nelson, he heard from you. That does not mean that he took everybody's advice, but he did hear it and he weighed it. And then as Presidents must, he arrived at a position that balanced all of the relevant considerations. And my own view is that out of that process, he got to the best and most balanced program for NASA, in-

cluding its human spaceflight dimension that the country can afford.

The CHAIRMAN. Thank you, Senator Nelson.

Senator Vitter?

Senator VITTER. Thank you, Mr. Chairman.

Mr. Bolden, as you know, a lot of our concerns are about the capability of the commercial sector to do what we are asking them to do on time, on budget, and putting, essentially, all our eggs in one basket.

It was reported to me in the conference call with Mr. Armstrong and Captain Cernan last week that you had—I think you referred to the call itself—for a couple hours you told them you would, “do whatever it takes,” to make commercial work including, “bailing them out,” even if that would mean, “a bigger bailout than Chrysler and GM.” What did you mean by that?

Mr. BOLDEN. I am not sure I said that, Senator. I am not sure who was in the room.

You know, as I have always said, I will do everything in my power to facilitate the success of the commercial entities in access to low-Earth orbit. I have to have that. The Department of Defense has to have it. Our intelligence community has to have it.

The budget today does not allow me to continue to build and operate in low-Earth orbit if I want to go explore. The contingency that I continue—I am a contingency planner. You know, I have to look at the possibility that the commercial sector may have difficulty, and we will do everything in my power to facilitate their success. So that is what I meant when I said anything about our—

Senator VITTER. Mr. Bolden, what I have read is more specific and different than what you just said. Did you use the sort of language I used?

Mr. BOLDEN. I do not remember using the sort of language you used. I do not remember that. This was just days ago.

Senator VITTER. OK, well, it made quite an impact on other folks on the conversation, and it raised my concerns at least.

Mr. BOLDEN. Senator, I always have people talk about conversations that I have had, and you know, I am involved in the conversation and I tell you what I said. I am not sure who else was in the room. I know who was in the room with me, and I know who was on the line with Gene and Neil.

Senator VITTER. OK.

Mr. BOLDEN. Unless someone was—

Senator VITTER. No. I am talking about direct participants who were taking notes.

As we sit here, do you think the commercial program is likely to stay on timetable and on budget?

Mr. BOLDEN. I think we are going to stay pretty much on timetable. If we go exactly the way that the schedule is laid out right now, it will be the first time in the history of any endeavor involving space that everybody that has made it on time. I expect that they will have technical difficulties and we will help them through them. They have already had some technical difficulties, as we do, and we work through them.

Senator VITTER. OK. In light of the continuation of *Orion*, why is it that NASA is taking actions which would constrain the funding of the program by shifting the termination liability costs onto the program, which is not the norm? I understand that is occurring in this case. That is not the norm, and there has been no decision by Congress in terms of funding.

Mr. BOLDEN. Senator, the termination liability is a factor that is in the contract of every supplier that NASA uses. It always has been. If you are referring to my letter, I just reminded them to read their contracts.

Senator VITTER. OK. Did you send the letter to the Hubble contractors or to the Webb telescope contractors? Did you send that letter to them?

Mr. BOLDEN. Senator, we did not have to send a letter to the Hubble contractors because they delivered without any problems. And in terms of James Webb, we continue to be constantly exercising oversight of them because I think as all of you know, it has been a fiscal challenge for us and it remains a fiscal challenge.

Senator VITTER. But are the termination liability costs being shifted onto the program? It is my understanding they are, which is not normal procedure. It is my understanding this is the case because of the Administration's plan as opposed to other—

Mr. BOLDEN. Congressman, the responsibility for termination liability lies with the company. And that is contractual. That is not something that we change. I cannot change it because it is in the contract.

Now, where the money lies—

Senator VITTER. What other contractors did you send this letter to?

Mr. BOLDEN. I sent it to all of the—we had it sent to the prime contractors of the Constellation program because this is—

Senator VITTER. What other programs' contractors did you send it to?

Mr. BOLDEN. We did not have to send it to anybody because we did not have any other program that had sent something to us saying that they were concerned about termination liability. But there are other programs in Government that are going through the same thing right now because of the same reason.

Senator VITTER. OK.

Mr. BOLDEN. Because the risk decision lies with the company, and if it is a publicly traded company, it lies with the board of directors. And in that particular case, they have to decide whether they are going to put the money in the bank or whether they are going to spend it on people and things, and it is a risk decision that they have to make. Normally when things are going along well, companies do not worry about it because they assume there is going to be no problem. But that is a risk that the company decides the level of risk they are going to take. And I think if you talk to any business, they will tell you the same thing.

Senator VITTER. Mr. Chairman, if I can have one final question for Mr. Holdren.

You talked about the budget constraints, which are certainly clear and obvious. But the bottom line is still that NASA's budget has an extra \$6 billion over 5 years. And it is not going primarily

to exploration. Maybe a billion is, and that is mostly research within that program. So it is a major increase going elsewhere.

Is it not true that with those significantly increased resources, certainly other things could have been done to focus more immediately on existing programs in human spaceflight?

Dr. HOLDREN. Senator, it is always true that one can make different choices about allocation. We think we made the best choices about allocation available to us under the circumstances. The decision to invest more in research and development, in game-changing technologies, in technologies that ultimately can take us faster and farther, as opposed to continuing to invest in the existing programs which were already way over budget and behind schedule, was a very conscious decision to invest in what have always been the sources of U.S. leadership. The source of U.S. leadership has always been advanced technology, and the Augustine committee's report and our own conclusion was that NASA had been under-investing in the advanced technologies that we will ultimately need to continue to lead, to go faster and farther in space. We could not have it both ways. We could not continue to invest in the old program at the levels that it was requiring and invest in these other possibilities.

Mr. BOLDEN. Senator, if I may add just one thing. And I suggest you ask Norm Augustine when he comes in on the panel because he will tell you it was a matter of taking \$6 billion and spreading it over 5 years for investments in technology development, aeronautics, science, and commercial or taking that \$6 billion chunk and putting it in 1 year for the Constellation program, not knowing how you would get to the next year. And Norm Augustine will tell you that.

His recommendation was, OK, let us take a modest amount. Let us take \$3 billion, and that was one of the options that they offered.

My fiscal responsibility to the President was to advise him that it would be much smarter to take \$6 billion and instead of putting it in 1 year of trying to catch Constellation up and then wondering where I was going to get the \$6 billion the next year, let us spread it over 5 years. Let us get a grip on our technology development. Let us restore some prominence to science and aeronautics.

And people are happy. You cannot find anybody in—scientists always argue about priorities, but it is hard to find somebody in the science or aeronautics community who will not tell you that this is an incredible budget for them. You cannot find a university president who will not tell you this is a great budget for them because they now—I just came from MIT and Harvard—

The CHAIRMAN. I do not want to interrupt you, but you are going to have to learn time limits, keeping it brief, otherwise you eat up Senators' times and they do not like that, and then they do not vote for what you want.

Mr. BOLDEN. Yes, sir.

[Laughter.]

The CHAIRMAN. Senator LeMieux?

Senator LEMIEUX. Thank you, Mr. Chairman.

General Bolden, after the last Shuttle flight—that is going to be the end of this year or the beginning of next. Is that what is currently scheduled?

Mr. BOLDEN. Yes, sir. That is our hope.

Senator LEMIEUX. Assuming that that is what happens, what will be the next NASA mission to low-Earth orbit?

Mr. BOLDEN. The next NASA mission to low-Earth orbit will be the next *Soyuz* that launches carrying a crew to the International Space Station at its next 6-month increment.

Senator LEMIEUX. When will be the next NASA mission that is powered with a NASA rocket?

Mr. BOLDEN. And I am not trying to be cute. The next NASA mission will be flown on a commercial rocket just as the Shuttle is. You know, it will be a commercial rocket that we leased instead of—

Senator LEMIEUX. Which rocket will that be?

Mr. BOLDEN. The first one will be SpaceX. It will be Falcon 9 in 2011, and then late 2011/early 2012, will be Taurus II, and then they will go through a sequence of demonstration flights that will allow us to take them to the point where they work on contract. Right now, everything is their dime. I gave them \$250 million apiece and they have to demonstrate with that money.

Senator LEMIEUX. Are those rockets taking us to the International Space Station?

Mr. BOLDEN. They will take us to the International Space Station.

Senator LEMIEUX. In 2011?

Mr. BOLDEN. Oh, no, sir. No, no, no. The first time that we will have a commercial rocket take us to the International Space Station with a crew will probably be about 2015.

Senator LEMIEUX. OK. So 5 years from now, your estimation is that those commercial rockets are going to be available to take us to low-Earth orbit.

Mr. BOLDEN. Yes, sir.

Senator LEMIEUX. Is that why you are saying that 2015 is the decision time or the President has articulated 2015 is the decision time on the heavy lift?

Mr. BOLDEN. No, sir. It has no connection with that.

Senator LEMIEUX. Why are we waiting till 2015—

Mr. BOLDEN. We are not waiting. I asked the President to challenge me, and I asked the President to give me a deadline of no later than 2015. Originally it was in 2015. If I have to wait until 2015 to make a decision, that prolongs the amount of time before I can start building a heavy lift launch vehicle. If I could give it to him tomorrow, I would. I cannot.

Senator LEMIEUX. You cannot—

Mr. BOLDEN. I cannot give him a recommendation on the architecture for a heavy lift launch vehicle because I am not smart enough.

Senator LEMIEUX. What about the Ares rockets?

Mr. BOLDEN. Ares are great rockets, but I am not sure that that is the best for the Nation. I am not sure it is the most cost-effective. I am not sure that we can sustain the technology that is going into Ares right now. I am not sure that we want to use solid rocket

boosters in first stage because I am trying to find a rocket that DOD, the intelligence community, and NASA can use, and that may not be a solid rocket motor. That may be LOX/RP or it may be LOX/hydrogen.

Senator LEMIEUX. How much money have we spent on the Ares rocket so far?

Mr. BOLDEN. On the Constellation program, we have spent about \$9 billion over the last 5 or 6 years, and not a dime of it has been wasted.

Senator LEMIEUX. So you are going to be able to use the money that we have already spent to make a decision on a new rocket as opposed to continuing the rockets?

Mr. BOLDEN. I am going to be able to use the products that came about from that \$9 billion of expenditure. Some rovers that have been developed as a part of the program that now I do not need to put permanent habitats on the Moon, a robot that we worked with General Motors in a Space Act agreement that we call R2, a dexterous robot that can throw a baseball but can also—

Senator LEMIEUX. My time—sorry, General. My time, as the Chairman says, is limited. So I want to get back to the rocket issue.

If we have already invested billions of dollars—

Mr. BOLDEN. Yes, sir.

Senator LEMIEUX.—in this heavy lift technology—

Mr. BOLDEN. No, sir, we have not.

Senator LEMIEUX. How much did we invest in the Ares rocket?

Mr. BOLDEN. Well, the only rocket that we have invested in so far has been *Ares I* because the investment in *Ares I*—it reduces the amount of money you have to pay for the *Ares V* rocket.

Senator LEMIEUX. How much did we invest in that?

Mr. BOLDEN. I will have to bring it back to you for the record because I cannot break out the \$9 billion among the different components of the Constellation program.

Senator LEMIEUX. Say that again. You cannot break out the different parts of the Constellation—

Mr. BOLDEN. I cannot for you right now at this table break out the amount that we have spent on the different components of the Constellation program.

Senator LEMIEUX. Is that something that you would submit for us?

Mr. BOLDEN. Yes, sir. We will get that for the record.

[The information referred to follows:]

Answer. As of June 2010, NASA has spent \$10.6 billion total on Constellation elements. This includes \$4.1 billion for *Ares I*; \$4.3 billion for *Orion*; and, \$2.2 billion for other Constellation elements such as ground operations and mission support elements.

Senator LEMIEUX. Let me ask quickly, since my time is short, about termination.

Mr. BOLDEN. Yes, sir.

Senator LEMIEUX. Are you telling vendors right now that you are terminating the Constellation program?

Mr. BOLDEN. No, sir, I am not. I cannot tell them that. They know, however, that the President's 2011 budget proposal—the lan-

guage is very explicit. It calls for termination of the Constellation program.

Senator LEMIEUX. But that is just his proposal.

Mr. BOLDEN. That is his proposal.

Senator LEMIEUX. You understand the law of the land right now is——

Mr. BOLDEN. Sir, I abide by the law of the land right now, and we are not terminating anything. I cannot do that lawfully.

Senator LEMIEUX. That is my time, Mr. Chairman. Thank you.

The CHAIRMAN. Thank you, Senator.

Senator Brownback?

Senator BROWNBACk. Thanks, Mr. Chairman.

I want to follow up on what Senator LeMieux was asking on the schedule on commercial spaceflight because this was a bit of new information to me. So NASA is going to be paying for initial flights in late 2011 by SpaceX on, was it, two vehicles that you are saying? Falcon 9 and then Taurus II?

Mr. BOLDEN. Falcon 9 and Taurus II are the first two commercial vehicles. Yes, sir.

Senator BROWNBACk. What is NASA paying for?

Mr. BOLDEN. Right now, NASA paid \$250 million to each SpaceX and Orbital as part of a Space Act agreement. That was to give them seed money so that they could go off and develop a commercial capability. That is all I paid.

Senator BROWNBACk. But they are going to launch something in late 2011?

Mr. BOLDEN. That will be the first flight that they will fly for me. Falcon 9 will actually launch the end of this month or early June, but that is not for me. That is for another customer. That goes in my data bank.

Senator BROWNBACk. OK. What will they fly for you in late 2011?

Mr. BOLDEN. It is a demonstration to demonstrate that they can get the vehicle to low-Earth orbit. You know, when they separate the Dragon module, they have to fly, navigate themselves to the International Space Station, get to a point where they can stop, and I can take it and berth it. So they have a number of demonstration flights that they have to fly. That is why I am not going to let them get anywhere close to the International Space Station.

Senator BROWNBACk. And that will be the first demonstration flight that they will be doing, is late 2011 for you?

Mr. BOLDEN. Let me go back and get it for the record for you, sir. I do not want to—because there are a series of flights that they have to fly, and I want to make sure that I am giving you accurate information on which because each flight is for a different purpose. It is an incremental progression. And I will get that to you.

[The information referred to follows:]

Answer. NASA'S Commercial cargo program includes two phases—the development phase which falls under the Commercial Orbital Transportation Services (COTS) program and the services phase, which falls under the Commercial Resupply Services (CRS) program.

NASA currently has two funded COTS partners, SpaceX and Orbital Sciences, which continue to make steady progress in achieving their cargo demonstration milestones:

- SpaceX was awarded a COTS agreement in August 2006 and as of mid-July, had completed 17 of 22 negotiated milestones for a total payment of \$253 million out of \$278 million. Space X is currently scheduled to conduct its first NASA demonstration mission in September 2010, followed by 2 additional demonstration flights in 2011.
- Orbital Sciences has completed 12 of 19 milestones for a total payment of \$140 million out of \$170 million, and the company is scheduled to complete its NASA demonstration mission in September 2011.

Senator BROWNBAC. How many flights are they going to be flying before 2015, which is when you send them up to the space station?

Mr. BOLDEN. Let me get that for the record, sir, because I do not want to give you—and it is just the same for Orbital. Each has a certain number of flights they fly under the COTS program that I paid for with the \$250 million, and then they go into a cargo resupply. But that is a contract. So for that, they make money every time they deliver something to orbit. But I will get you the data on the specific scheduled dates of the flight.

[The information referred to follows:]

Answer. On December 23, 2008, NASA awarded Commercial Resupply Services (CRS) contracts to Space Exploration Technologies (SpaceX) and Orbital Sciences Corporation (OSC) for the delivery of cargo to the International Space Station (ISS) after the retirement of the Space Shuttle. The CRS contracts are firm-fixed price, Indefinite Delivery Indefinite Quantity procurements with a period of performance from January 1, 2009, through December 30, 2015 (the contractor can make deliveries on missions ordered prior to December 2015 through December 2016). NASA ordered 8 flights from OSC and 12 flights from SpaceX under the CRS contracts. While launch readiness dates have only been established for the first 2 of these 20 flights so far, NASA anticipates that up to 16 will have taken place before 2015.

Senator BROWNBAC. Good. I think for the Chairman, for me, and for I think the whole committee, the more specific you are on this—because, obviously, people have a lot of questions about, now, how are you going to stand up this new capacity.

Will these be manned flights, the late 2011 ones, by SpaceX?

Mr. BOLDEN. No. It is cargo only.

Senator BROWNBAC. So, no, there will not be—

Mr. BOLDEN. We have got a long way to go. We have a long way to go, and when I say a long way to go, they have got to demonstrate their ability to get cargo to orbit safely.

Senator BROWNBAC. In an unmanned vehicle.

Mr. BOLDEN. In an unmanned vehicle. And there are several flights along that—

Senator BROWNBAC. When is your year marker for when they will have a manned spaceflight before it goes to the station?

Mr. BOLDEN. My target right now is for them to fly their first crewed flight for me in 2015.

Senator BROWNBAC. First crew flight.

Mr. BOLDEN. First crew.

Senator BROWNBAC. So the first one will go to the space station in 2015?

Mr. BOLDEN. Yes, sir.

Senator BROWNBAC. Now, I am struck by the Augustine report, and I am a fan of Norm Augustine. I have known him for some years, and I think he is just a really solid American. But I am troubled about how it feels like we are losing control or it feels like we

are losing leadership in the manned space arena. And yet, I gather from his data and the things he is saying, he says there is just not another way for us to continue human spaceflight on the budget that he believes we are willing to do. Is it strictly a dollars and cents issue then, Administrator?

Mr. BOLDEN. Senator, everything is a dollar and cents issue, you buy it by the pound. If we want to explore beyond low-Earth orbit, we have to free NASA of the responsibility for day-to-day operations. I have to free myself of the \$2 billion annual infrastructure cost. If I do not fly a single Shuttle mission, I pay \$2 billion a year just for the infrastructure. I have got to be able to free myself of that so that I can go beyond low-Earth orbit. And that is the importance of the commercial entities in providing transportation to low-Earth orbit.

Senator BROWNBAC. Because my time is about up, is there any other way for us to continue an aggressive human spaceflight program with the budgetary dollars you have talked about other than the one you have prescribed?

Mr. BOLDEN. Senator, we will continue an aggressive human spaceflight program because I have astronauts. I just selected a group of astronauts this past year, and I have a number of them who are in training to fly on the International Space Station right now through 2015, and we are getting ready to make subsequent crew assignments to fly through 2020. So we do not intend to stop going to space. As Senator Hutchison says, we have got a lot of work to be done on the International Space Station, and I cannot take a—

Senator BROWNBAC. No, I understand. But the Russians are going to cart us back and forth.

Mr. BOLDEN. Senator, the Russians have been carting us back and forth for 2 years.

Senator BROWNBAC. I understand that. I am asking you just point blank is there another way for us to be able to continue an aggressive human spaceflight program other than the one you have outlined here.

Mr. BOLDEN. Within the budget?

Senator BROWNBAC. Within the budget.

Mr. BOLDEN. The program of record, Constellation, will not enable me to do what I just told you I want to do.

Senator BROWNBAC. Thanks, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Brownback.

I have one short question. I think Senator Nelson has a question and Senator Hutchison, if she wants.

Senator HUTCHISON. I have got about 20 more questions, but I really do not want to make the astronauts and Mr. Augustine keep waiting. So I am really so sorry because this is so important.

The CHAIRMAN. I know. I know.

I am going to ask one short question. This is all to me actually very interesting. And the putting together of this was very difficult. There was a lot of kind of combativeness and suspicion. You heard some of the comments of sort of a secret society formation of the plan, for which Norm Augustine—I guess he can talk about how he joined that group. But there is in my mind, frankly, a sense of not being settled or comfortable with where we have been going. Part

of that is based upon the history and the mystery and the mysticism and the culture and the romance in a sense of 1962 and thereafter.

America needs to catch up in the world. We are behind in virtually everything we do from telecommunications to science, technology, engineering, and math. So let me just take science, technology, engineering, and math for one second and ask one question. That has nothing to do with human spaceflight. I understand that. Human spaceflight is a given. Going into the far reaches of the universe is something which I will ask about later on on another day.

But if we do not do our work in science, technology, engineering, and math, all of what you are talking about and all of which you were, Dr. Holdren, is going to become less and less possible as fewer and fewer Americans attach themselves to those things which lead to what NASA does.

So I notice in the budget that you have what I would call inspiring the next generation. It used to be you just mentioned the name "John Glenn" or the two astronauts which will come out very shortly or yourself—

Mr. BOLDEN. Those were the good old days, Senator. They do not even recognize my name.

The CHAIRMAN. But there is a new kind of a hunger in the new generation. The head of the Discovery Channel was here last week and told us that between the ages of 12 and 22, more young people of their own volition, obviously, watch the Discovery Channel and all of its uncovering of the mysteries of science and all the rest of it, technology, et cetera, than watch ESPN and I assume other cable channels. A fascinating, powerful statement. A young generation waiting to be inspired, of their own choice reaching out to be inspired by products which happen to be there.

So you have something called an education budget and you are putting less than 1 percent of NASA's budget into what I call education, which I look upon as future generations waiting to participate in ventures. Can you respond?

Mr. BOLDEN. Yes, sir. There are direct and indirect ways that we contribute to education. I am glad you asked the question. NASA has 312 first robotics teams that we sponsor, more than any other Federal agency, more than any other company in the world. If you do not know about First Robotics, I would recommend you go. It is fascinating. I went to the International championships. That inspires kids.

We have something that is flying on the International Space Station right now called Spheres. They are just round balls produced at MIT that up until now, for about—I want to say since 2006 have been flying around inside the International Space Station programmed by college students who are doing research with the Summer of Innovation, a program that we are rolling out. We just rolled out the first award on Monday in Boston with Governor Patrick. We are going to extend the opportunity for middle school students to program a Sphere or a set of Spheres that is going to fly around inside the International Space Station. To me that is inspirational. I do not care what anybody says. A kid does not have to become an astronaut.

Dr. HOLDREN. Mr. Chairman, the President and I, as well as Administrator Bolden, completely agree with you about the priority that we have to give to science, technology, engineering, and math education. The President rolled out last November an Educate to Innovate initiative based around partnerships with the private sector including, by the way, the Discovery Channel. The Discovery Channel and Time Warner cable are combining to offer 2 hours of after-school exciting science programming free of commercials every day on cable channels around the country. Over half a billion dollars is pledged in money and in-kind support from private industry and foundations to help us improve STEM education in this country. Administrator Bolden and I both this week were out as part of National Laboratory Day, which is all about improving the science and engineering labs available in every middle school and high school in this country. NASA is part of an administrative partnership that engages as well the NSF, the Department of Energy and, of course, the Department of Education. We are doing a lot in that domain. The President is absolutely ecstatic about what we are getting done.

And we could not agree with you more. But these things are all related. NASA's success, DOE's success, NSF's success is linked to the success of the education programs we promote through the White House and the Department of Education. It is all coming together.

The CHAIRMAN. I thank you, sir.

Senator Nelson?

Senator NELSON. Thank you, Mr. Chairman.

Dr. Bolden, did you have any discussions with the Department of Defense upon the effect of the cancellation of the solid rocket motor program in NASA on DOD?

Dr. HOLDREN. You said, I think, Dr. Bolden, so I am not sure which of us—

Senator NELSON. Dr. Holdren.

Dr. HOLDREN. OK. Yes, we did. We had a number of discussions with folks in the Department of Defense, and I have to say in all honesty the Department of Defense is still looking at it. Those initial conversations communicated to us that there would be an impact, but it did not appear to be an unmanageable impact. And those considerations are going on, I understand, even as we speak. But I continue to believe—

Senator NELSON. Those considerations are going on as you speak, but would it surprise you that there is a complete record in front of the Senate Armed Services Committee by General Chilton, who is one of the generals charged with the strategic defense of the country, as well as the other general, General Cartwright, who is the Vice Chairman of the Joint Chiefs, who has in his portfolio the strategic defense, that in fact the DOD was absolutely shocked that NASA suddenly came up with this program to cancel the testing on the solid rocket motor since NASA has 70 percent of the industrial base of solid rocket motors, of which the remainder the Defense Department is absolutely reliant on? Does that surprise you?

Dr. HOLDREN. Well, first of all, Senator, the DOD is a big place and we did not talk to everybody. We are aware that there is going to be an impact. The DOD obviously has an interest in this domain.

I think that the DOD is probably capable of supporting its interests in this domain although it may mean higher costs per unit for the DOD in acquiring the solids that they need. I am not saying there is no issue there, and I am not surprised that a variety of analyses exist in the Department. But I believe that there will be a solution to that issue going forward.

Senator NELSON. Dr. Holdren, did you have a discussion with Administrator Bolden within the week before the budget was rolled out to let him know what the final President's proposal was going to be?

Dr. HOLDREN. You say within the week. We certainly had it within the 2 weeks. It was well before the last week, and yes, we did.

Senator NELSON. So, General, you knew what the President's proposal was going to be even though you were in Israel.

Mr. BOLDEN. I actually found out before I went to Israel. I was in Israel the week before the rollout and I came back that Thursday night, but we had already met on the budget the week before.

Senator NELSON. All right.

General can you tell me is there a discussion going on within NASA and OSTP now that you all are considering adding one more Shuttle flight to the manifest?

Mr. BOLDEN. Senator, that discussion has gone all the way up. I have told people that there is potential that I would like to fly the Launch on Need mission, and it would be for logistics reasons. It would have nothing to do with jobs or anything else. If I have spare supplies that I can get on the International Space Station, I would like to take every opportunity to do that.

It is not an easy decision, though, because I will have no Launch on Need vehicle to back it up, and that is not trivial, that decision to do that.

Senator NELSON. But you do have the plans that would the worst happen on ascent so that the crew could take safe refuge in the ISS.

Mr. BOLDEN. Senator, we have contingency plans to include what happens to the crew if they cannot get to the ISS because everybody always—one of the things I hate is everybody always assumes you get to the International Space Station. That is a long way away. That is 200 miles. If you have a problem on ascent, as you remember, when part of the back end of the orbiter comes off, you do not get to the ISS. So that is one of the reasons that I do not want that to happen and I say it is not a trivial decision.

Senator NELSON. What would be the cost of continued *Ares I* testing?

Mr. BOLDEN. Senator, I will get you the exact numbers, but it is in the neighborhood of about \$1 billion to \$1.6 billion. And the variation comes because if you are testing an *Ares I* vehicle and the plan is that it will morph into the *Ares V* vehicle, then you spread the cost across both vehicles. If all I am doing is flying an *Ares I* test so that I can keep people working, it goes up to \$1.6 billion because there is nothing else to help absorb that cost, and so it all goes to *Ares I*. And that is why in our discussions I have said as much as I am a tester, I cannot ask any more to allow me to test

an Ares vehicle if there is something else I can use to get the same test of an *Orion*-type vehicle or anything else done.

Senator NELSON. And speaking of *Orion*—and I know you want me to quit my questioning—why do we want a half-baked *Orion* instead of a full-baked *Orion*?

Mr. BOLDEN. Senator, we do not want a half-baked *Orion*. What we want is an incrementally developed crew module that can take people beyond low-Earth orbit.

Again, what I do not want to do in any crew module is I do not want to settle on the design and configuration in 2010 when I know that the first time I am going to send a human beyond low-Earth orbit—the earliest is 2020. So if I settle on a vehicle today, fly it in 2013, and the crew has to live with that same vehicle and that same configuration for 7 more years, they are going to be flying on a vehicle that is 7 years old. I do not want the *Orion* that is going to go to the Moon and to Mars and to an asteroid—I do not want that final configuration internally made until as close as possible to flight.

Senator NELSON. Then why have a half-baked one? Why not early on the *Soyuz*?

Mr. BOLDEN. Senator, I need to have my people, American industry, continue to work on spacecraft. Otherwise we lose the skill. We lose the talent.

Also, it is important for national pride and other things that we have an American-built vehicle that is docked to the International Space Station. And I can do that with the foundational vehicle that will be the basis for what is going to take us beyond low-Earth orbit.

The CHAIRMAN. We have reached a point now where we have only time for Senator Warner to ask, hopefully, just one question. We have two astronauts and Dr. Augustine waiting for us. We have not treated them fairly. On the other hand, we have really had just one and a half rounds of questions. The subject is that interesting and that controversial. So I do not apologize for that.

Senator Warner?

**STATEMENT OF HON. MARK WARNER,
U.S. SENATOR FROM VIRGINIA**

Senator WARNER. Thank you, Mr. Chairman. Let me say this is a nice break from derivatives and high frequency trading and some of the other things we have been dealing with on the floor.

Let me also follow up very quickly, realizing my time is short. You mentioned the educational foundation. I do think there are interesting opportunities to leverage off of things. I think about the X Prize Foundation and the kind of energy that that generated in this sector.

I know how my colleague from Florida feels and I understand I missed some of the earlier conversations, some controversy around the issue of the commercialization. I think it holds some great possibilities and opportunities. Wallops has a facility in the Commonwealth of Virginia.

But one thing I am interested in, assuming for a moment that commercialization moves forward, and part of the challenge of NASA will be to ensure, as I think earlier questions have pointed

out, the safety of these commercial missions, particularly going up to the ISS—you know, have you thought through how you set those standards particularly in the commercial context and is there some analogy what we could draw from, NASA Langley working with FAA on setting safety standards around commercial aircraft that we could perhaps utilize again from a—

Mr. BOLDEN. Senator, we have thought it through very seriously and we continue to think it through. And I have a group right now that is going to report to me on something I call insight and oversight. Senator Rockefeller talked about how we cannot continue to do things the way we do. We have too many boards and panels and oversight committees in NASA, and I have asked our folks to find a way we can get back to something reasonable. We do not need all the oversight committees that we have. That is costly and it consumes time.

A great example of the type of oversight that I would like to have is our relationship with the Russians in *Soyuz*. The Russians do a flight—you know, before every flight, they do a flight readiness review just like we do with the Shuttle. I have people from my Space Operations Mission Directorate sitting in Moscow in the flight readiness review. They are a member of the team. When the Russians had their two dynamic reentries in the last couple of years, while we were not a part of the engineering investigation, we got all of the data on the mishaps and we learned what had happened and we learned what they did to correct it. And so I will use that sort of as a model.

The disadvantage to commercial is that they do not have the experience that *Soyuz* has. We have 90 successful missions on *Soyuz*. So that makes me a lot more comfortable with them than, say, an upstart company in commercial development. But I will make them successful because I will establish standards and they are looking at them now to make sure we are not being unreasonable. So we have thought about it a lot.

Senator WARNER. I would just point out again, that the previous experience that NASA Langley has with FAA in terms of commercial aviation. There may be some lessons learned—

Mr. BOLDEN. The work that Langley does in NextGen, the next generation air transport system—we were talking about human spaceflight, but that is incredible. Langley, Glenn, Ames Research Center—we are all intimately involved in trying to make aviation, general aviation and commercial aviation, flights safer and more efficient for everybody around the world. And NextGen is going to do that.

Senator WARNER. And lessons learned there could perhaps be implemented—

Mr. BOLDEN. Every day we are learning new lessons, yes, sir.

Senator WARNER. I have got other questions for the record, Mr. Chairman.

The CHAIRMAN. You can submit those for the record. Right.

I want to thank both of you gentlemen. This has been a very interesting first panel. It has taken a long time, but that is because I think there is uncertainty. I have questions about NASA. I always have. I still do. But we are working our way toward something and there are conflicting points of view. I mean, there are

some people who just simply want it this way and others that want it that way, and then some are trying to find a third way and I guess I am in that category.

In any event, I really thank you, Dr. Holdren, extremely for being here and also you, General, for being here. I honor you both and I thank you both.

Dr. HOLDREN. Thank you very much.

The CHAIRMAN. We will now be in recess for 30 seconds.

[Laughter.]

[Pause.]

The CHAIRMAN. If we could hurry up this process, please. To the press and to anybody else, we are looking for our two good astronauts and Dr. Augustine. We need them at the witness table.

What is the problem with getting the next panel in here? They are right next door. Here they come.

The panel will be seated, please, and the press will finish with their obligations and we will proceed.

[Laughter.]

The CHAIRMAN. I want order in this hearing room and, JJ, you will enforce it.

I want to welcome Mr. Neil Armstrong, who was Commander of Apollo 11; Captain Eugene Cernan, who was Commander of Apollo 17; and Norman Augustine, who I have known for many years and who is the Chairman of the Review of the U.S. Human Spaceflight Plans Committee. We will start with you, Mr. Armstrong.

**STATEMENT OF NEIL A. ARMSTRONG, RETIRED ASTRONAUT,
FORMER COMMANDER, APOLLO 11**

Mr. ARMSTRONG. Thank you, Mr. Chairman. Mr. Chairman, members of the Committee, I want to express my sincere appreciation for being invited to present the views on NASA's new plan for human spaceflight.

New non-classified national program concepts are typically accompanied by substantial review and debate in a number of venues. That process is occasionally frustrating, but it assures that all the major issues, performance, cost, funding, safety, schedule, and so forth, will be examined in some detail prior to a public proposal.

After the tragic loss of *Columbia* and its crew and the completion of the accident investigation, Admiral Gehman, the Chairman of the *Columbia* Accident Investigation Board, noted that NASA needed a long-term, strategic guiding vision. President Bush, after reflection, proposed such a vision: finish the International Space Station, return to the Moon, establish a permanent presence there, and venture onward toward Mars.

As this committee well knows, that vision was analyzed, debated, and improved upon with the Congress for nearly 2 years. You then concluded, nearly unanimously, that it was the appropriate policy for our country. Three years later, after a change in congressional control, the policy was once again approved, although it was still not adequately funded.

With regard to President Obama's 2010 plan, I have yet to find a person in NASA, the Defense Department, the Air Force, the National Academies, industry, or academia that had any knowledge of

the plan prior to its announcement. Rumors abound that neither the NASA Administrator nor the President's Science and Technology Advisor were knowledgeable about the plan. Lack of review normally guarantees there will be overlooked requirements and unwelcome consequences. For this plan that is worrisome.

America has invested substantially for more than half a century to acquire a position of leadership in space. But for any organization, a public utility, an airline, a university, or an NFL team, to maintain a leadership position requires steadfast determination and a continuing investment in the future. That investment must be made wisely.

I believe that so far our national investment in space and our sharing of that knowledge, gained with the rest of the world, has been made wisely and has served us very well. America is respected for its contributions it has made in learning to sail on this new ocean. If the leadership we have acquired through our investment is simply allowed to fade away, other nations will surely step in where we have faltered. I do not believe that would be in our best interests.

I am very concerned that the new plan, as I understand it, will prohibit us from having human access to low-Earth orbit on our own rockets and spacecraft until the private aerospace industry is able to qualify their hardware under development as rated for human occupancy. I support the encouragement of newcomers toward their goal of lower cost access to space. But having cut my teeth in rockets more than 50 years ago, I am not confident. The most experienced rocket engineers with whom I have spoken believe that it will require many years and substantial investment to reach the necessary level of safety and reliability.

If these experts are correct, the United States will be limited to buying passage to the International Space Station from Russia and will be prohibited from traveling to other destinations in low-Earth orbit such as the Hubble space telescope or any of the frequently mentioned destinations that are out on the space frontier.

As I examine the plan, as stated during the announcement and the subsequent explanations, I find a number of assertions which, at best, demand careful analysis and, at worst, do not deserve any analysis.

I do believe if the national space plan is subject to the normal review process of this Congress, the aerospace industry, and the reliable experts that we know in the military and the aerospace community, America will be well served.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Armstrong follows:]

PREPARED STATEMENT OF NEIL A. ARMSTRONG, RETIRED ASTRONAUT,
FORMER COMMANDER, APOLLO 11

Mr. Chairman, and members of this Committee, I want to express my sincere appreciation for being invited to present my views on NASA's new plan for human spaceflight. As I have come to accept that my opportunities to once again see our beautiful planet Earth from afar are limited, I can speak my mind without fear of jeopardizing my crew status.

New non-classified national program concepts are, typically, accompanied by substantial review and debate in a number of venues. That process is occasionally frustrating, but it assures that all the major issues (performance, cost, funding, safety, schedule etc.) will be examined in some detail prior to a public proposal.

After the tragic loss of *Columbia* and its crew, and the completion of the accident investigation, Admiral Gehman, the Chairman of the *Columbia* Accident Investigation Board, noted that NASA needed a long-term, strategic, guiding vision. President Bush, after reflection, proposed such a vision: finish the International Space Station, return to the Moon, establish a permanent presence there, and venture onward toward Mars. After completion of the very detailed Exploration Systems Architecture Study (ESAS), that vision became a Program known as Constellation. A high level panel of human spaceflight veterans and a highly experienced independent review team vetted the ESAS conclusions. ESAS results were briefed to senior Administration officials including OSTP, OMB, USAF Air Staff and DDR&E. Of course, this Committee as well as other Congressional committees and subcommittees were briefed.

As this committee well knows, that vision was analyzed, debated, and improved upon within the Congress for nearly 2 years. You then concluded, nearly unanimously, that it was the appropriate policy for our country. Three years later, after a change in Congressional control, the policy was once again approved, although it was still not adequately funded.

With regard to President Obama's 2010 plan, I have yet to find a person in NASA, the Defense Department, the Air Force, the National Academies, industry, or academia that had any knowledge of the plan prior to its announcement. Rumors abound that neither the NASA Administrator nor the President's Science and Technology Advisor were knowledgeable about the plan. Lack of review normally guarantees that there will be overlooked requirements and unwelcome consequences. How could such a chain of events happen? A plan that was invisible to so many was likely contrived by a very small group in secret who persuaded the President that this was a unique opportunity to put his stamp on a new and innovative program. I believe the President was poorly advised.

America has invested substantially for more than half a century to acquire a position of leadership in space. But for any organization, a public utility, an airline, a university, or an NFL team, to maintain a leadership position requires steadfast determination and a continuing investment in the future. That investment must be made wisely.

I believe that, so far, our national investment in space exploration, and our sharing of the knowledge gained with the rest of the world, has been made wisely and has served us very well. America is respected for the contributions it has made in learning to sail upon this new ocean. If the leadership we have acquired through our investment is allowed simply to fade away, other nations will surely step in where we have faltered. I do not believe that this would be in our best interests.

I am very concerned that the new plan, as I understand it, will prohibit us from having human access to low-Earth orbit on our own rockets and spacecraft until the private aerospace industry is able to qualify their hardware under development as rated for human occupancy. I support the encouragement of the newcomers toward their goal of lower cost access to space. But having cut my teeth in rockets more than 50 years ago, I am not confident. The most experienced rocket engineers with whom I have spoken believe that will require many years and substantial investment to reach the necessary level of safety and reliability. Business analysts believe that at least two qualified competitors would be required to have any chance of reducing ticket prices. They further believe that a commercial market large enough to support even one competitor is unlikely.

If these experts are correct, the United States will be limited to buying passage to the International Space Station from Russia, and will be prohibited from traveling to other destinations in LEO, such as the Hubble Space telescope, or any of the frequently mentioned destinations out on the space frontier.

As I examine the plan as stated during the announcement and subsequent explanations, I find a number of assertions which, at best, demand careful analysis, and at worst, do not deserve any analysis.

The Augustine Commission found that "NASA essentially has the resources either to build a major new system or to operate one, but not to do both." In that context, the principal choices would be develop the Constellation Program or to continue to operate the Shuttle and the ISS.

The Shuttle, a stellar low-Earth orbit machine, is scheduled for termination this year. It has a great deal of versatility and can do many things well, although the current protocol limits its operation to the ISS orbital inclination. While the Shuttle is four decades old technology, it has been operating well and could be expected to be able to continue to do so for some years if approved. Shuttle operation is, however, very costly. It could not be justified solely as a crew taxi, but would, and should, continue to carry cargo, and continue to perform the many other services it now provides.

The now to be canceled Constellation program showed promise to fulfill lofty goals with a high level of safety and flexibility. Constellation would also be very costly. Critics claim it is “unexecutable,” primarily because it has been underfunded.

The new 2010 plan goals are largely undefined in the near term but have been characterized as supporting ISS through 2020 and finding breakthrough technology to allow flying to a near Earth asteroid and to Mars at some time in the future.

These are vastly different plans and choosing the proper path is vital to America’s continued space leadership.

Orion

Amendments to the 2010 plan were announced in the President’s April 15 speech at the Kennedy Space Center. He stated that the canceled *Orion* Spacecraft would be given new life as an emergency return vehicle from the International Space Station. Such a craft would be necessary if an Orbiter or Soyuz was not available, if the ISS had a major emergency, or in case of a medical emergency.

In the first decade of ISS operation we have not needed such a spacecraft, and, hopefully, in the remaining ISS lifetime, we will not need one. However, there certainly is merit in having emergency escape ability. The difficulties crop up when we examine the detail of the requirements necessary for such a vehicle.

Configuration studies of emergency return vehicles have been going on for decades, NASA had a selected vehicle for development, the X-38, a lifting body which had substantial promise, but was canceled for budgetary reasons in 2002.

The complexities of such a craft, required because of the wide variety of emergency situations that could be encountered, indicated that a near ballistic shape such as *Orion* would be inferior to a configuration with higher aerodynamic performance.

Because the *Orion Light*, as described, would be capable of carrying humans on only a return to Earth trajectory and not from Earth to the ISS, its utility would not seem to compare well with the Soyuz and its two-way trajectories that are currently used. The time and cost of this development including the autonomous or remotely controlled rendezvous and docking would appear to be significant. It appears that this would be a very expensive project with limited usefulness.

Heavy Lift

The second Florida announcement concerned studying heavy lift rockets with the objective of choosing a best design by 2015, then beginning construction and test. It was asserted: “That’s at least 2 years earlier than previously planned . . . and that’s conservative, given that the previous program was behind schedule and over budget.” The assertion is disingenuous, in that it is comparing an unknown project in the future with a known project already underway for some years. The “previous program” is assumed to be the *Ares V* which depends on the same 5.5 segment SRBs and J-2X engines of the recently canceled *Ares I*. The delay in the *Ares I* development was due to under funding as a result of Shuttle Return to Flight requirements, ISS requirements, 2004 hurricane damage, OMB reductions and FY 2010 Budget reductions. The budget reductions for Constellation through 2020 totaled more than \$20 billion. Considering those realities, some members of the Augustine Committee concluded that the Ares program was being quite well managed and in reasonably good shape.

Knowledge in Heavy Lift rockets is currently substantial. A great deal of such study has been completed in recent years as a part of the normal NASA and military studies. As of the time I write this testimony, NASA’s website describes the *Ares V* as follows: “Under the goals of NASA’s exploration mission, *Ares V* is a vital part of the cost-effective space transportation infrastructure being developed by NASA’s Constellation Program to carry human explorers back to the Moon, and then onward to Mars and other destinations in the solar system.”

While Ares has been criticized for being late and over budget, the cause of that condition is largely understood. It seems appropriate that the reason for discarding all this work should be explained to this committee.

A heavy-lift rocket derived from the Shuttle (SDHLV) has often been suggested as a useful vehicle and could be produced in far less time than that proposed in the 2010 plan. The technology and hardware, for this development is already largely available and would not require 5 years of study to implement.

Workforce

The plan’s consequent expected loss of jobs in space communities has been widely reported. This committee knows far more about such matters than I and I will not comment on it. I am concerned, however, about workforce issues. Shuttle termination and Constellation cancellation will result in widespread breakup of design,

manufacturing, test and operating teams that will be expensive and time consuming to reassemble when they are once again needed.

With the job market so tight, individuals who are in programs expected to be canceled or cut back are leaving to pick up one of the few available jobs. Some of the best and the brightest are already leaving because of the uncertain future. Maintenance of a quality workforce is vital to a successful spaceflight program and attention to this consequence of the new plan must be considered.

Safety

It was asserted that by buying taxi service to Low-Earth Orbit rather than owning the taxis, "we can continue to ensure rigorous safety standards are met". The logic of that statement is mystifying. Does it mean that safety standards will be achieved by regulation, or contract, or by government involvement? Does it mean that the safety considerations in the taxi design, construction and test will be assured by government oversight? The Augustine Committee report is quoted as follows: "Thus, the Committee views any commercial program of crew transport to ISS as involving a strong independent mission assurance role for NASA." The cost of that government involvement will be substantial and that cost must be acknowledged in the total cost of the service.

The private company spacecraft, to my knowledge, have not been as rigorously analyzed for safety as have existing rockets, Ares and Shuttle derivatives, but it must be noted that *Ares I* enjoys, by a significant margin, the highest safety rating of the configurations studied.

I have highlighted just a few of the many issues and questions engendered by the 2010 NASA plan. I do believe, if the National Space Plan is subject to the normal review process of this Congress, the aerospace industry, and the reliable experts we know in the military and aerospace community, America will be well served.

The CHAIRMAN. Thank you, Mr. Armstrong, very much.
Captain Cernan?

STATEMENT OF CAPTAIN EUGENE A. CERNAN, USN (RETIRED), COMMANDER, APOLLO 17, ASTRONAUT (RETIRED)

Mr. CERNAN. Thank you, Mr. Chairman. I also want to again thank you for inviting me here today to express my personal views concerning the Administration's 2011 budget as it pertains to America's role in the future of human space exploration.

One month ago, Neil Armstrong, Jim Lovell, and I released an opinion paper expressing our concern over the Administration's proposed space budget. We spent a great deal of time writing and refining over and over again this document, choosing our words very carefully, words like "devastating," "slide to mediocrity," and "third rate stature," primarily because we did not want to be misunderstood, nor did we want to be misinterpreted. We particularly wanted to avoid any political overtones because since the beginning days of NASA, its support has come from traditionally bipartisan politics. It has transcended our political differences.

We have recently heard a lot of eloquent verbiage about the exploration of space, landing on an asteroid, circling Mars, and some day maybe even landing on the Red Planet. There is talk about a decision yet to come about building a large booster which might ultimately some day almost take us to the far reaches of this universe. There is, however, no detail, no specific challenge, and no commitment as to where or specifically when this exploration might come to pass. When one examines in detail the 2011 budget, nowhere can be found 1 penny—not 1 penny—allocated to the support of space exploration. Yes, there has been much rhetoric about transformative technology, heavy lift propulsion, research, robotic precursor missions, and these are all very worthwhile endeavors. Yet, nowhere—nowhere—do we find any mention of human space

exploration, and nowhere do we find a commitment in dollars to support this national endeavor. Neil, Jim Lovell, and I have come to a unanimous conclusion that this budget proposal presents no challenges, has no focus, and is in fact a blueprint for a mission to nowhere.

In this proposed budget, we find several billions of dollars allocated to developing commercial human access to low-Earth orbit based upon the assumptions and claims by those competing for this elusive contract who say they can achieve this goal in little more than 3 years and can do it for something less than \$5 billion.

Based upon my personal experience and what I believe is possible, I believe it might take as much as a decade, a full decade, and the cost may be two to three times as much as they predict. Although I strongly do support the goals and ideals of commercial access to space, the folks who propose such a limited architecture do not yet know what they do not know. There is a myriad of technical challenges in their future yet to be overcome, safety considerations which cannot be overlooked or compromised, as well as a business plan and investors they will have to satisfy. All this will lead to unplanned delays which will cost the American taxpayer billions of unallocated dollars and lengthen the gap from Shuttle retirement to the day we can once again access low-Earth orbit, leaving us hostage as a Nation to foreign powers for some indeterminate time in the future.

This may be a sensitive point because I am going to mention something about a dear friend who I have the ultimate respect for, Charlie Bolden, because we did have a briefing last week, and it was in that briefing that Charlie expressed some concern over the potential of the commercial sector to be successful in any reasonable length of time. He indicated we might have to subsidize them until they are successful. And I can say with authority, because I wrote this down and I put the word "wow" right next to it because Charlie did say it may be a bailout like GM and Chrysler. As a matter of fact, it may be the largest bailout in history.

The United States, through NASA, has spent a half a century, Mr. Chairman, learning what we did not know, finding answers to questions we were not smart enough to ask at the time, developing technology that was needed to meet the challenge and get the job done. We came from Alan Shepard's flight in 1961 to the Space Shuttle and the International Space Station today, by the way, with a side trip or two to the Moon along the way. The evolution of this learning process was not without cost, not just in dollars, but in the lives of our friends and our colleagues. It took the courage, the effort, the dedication, and the self-sacrifice of thousands of Americans out there who allowed us to come this far this quickly. And although we paid dearly for our mistakes, it is a testimonial to their commitment and American ingenuity that everyone who went to the Moon came home. Therein is a lesson we cannot afford to ignore, and I ask the question, is this the NASA we want to transform?

For the sake of time, I will not go into my thoughts and concerns about game-changing technology without a goal or the fact that we may or may not some day make a decision to build a heavy lift

booster or the fact that I have major concerns about an *Orion* “light” because I went into detail in my written testimony.

Well, let me go back to Constellation because it is an architecture that over a 5-year period has gone through detailed review processes and been vetted by every Government agency from the OMB to the DOD and certainly by NASA—every agency that has any ownership interest in any technical, scientific, budget, or benefit that might be derived from human space exploration. In addition, an arsenal of the best engineers, scientists, and management experts in America’s aerospace community added their knowledge and expertise to the review of the proposed Constellation architecture before it ever became a program worthy of consideration. And appropriately, as has been said already, under the law, both houses of Congress overwhelmingly with bipartisan support approved and agreed that Constellation should go forward.

It is unknown how much time and thought was put into the existing budget proposal for 2011 or by whom this proposal was generated, but it is common knowledge that few, if any, of those government agencies referred to above were asked to participate nor, of significant note, was the DOD or the engineering or management expertise that exists throughout NASA today. This leads one to the conclusion that this proposal was most likely formulated in haste within the Office of Management and Budget with little or with no input, by his own admission in previous testimony, the NASA Administrator or, I know for a fact, by NASA center directors or senior NASA management. And if that were the case, the originators were quite likely promoting their own agenda rather than that of NASA and America’s commitment to human space exploration.

The space program has never been an entitlement. It is an investment in the future, an investment in technology and jobs and world respect and leadership, and perhaps most importantly, in the inspiration and the education of our youth.

Mr. Chairman, you asked how much of the budget has gone into education. That goes in the paperwork and the spinoff information. The inspiration for our youth came when Neil Armstrong walked on the Moon. It is a freebie that comes from space exploration. Those best and the brightest minds at NASA and throughout the multitudes of the private contractors, large and small, did not join the team to design windmills, but to live their dreams of once again taking us where no man has gone before.

In closing, Mr. Chairman, I would like to say America’s human spaceflight program has for a half a century risen above partisan differences from Eisenhower to Kennedy to the present day. The challenges and accomplishments of the past were those of a Nation, never of a political party, nor were they of any individual agenda. Those flags which fly today in those valleys on the Moon are not blue flags and they are not red flags. They are American flags. If we abdicate our leadership in space today, not only is human spaceflight and space exploration at risk, but I personally believe the future of this country and, thus, the future of our children and grandchildren as well. Now is the time for wiser heads in Congress of the United States to prevail. Now is the time to overrule this ad-

ministration's pledge to mediocrity. Now is the time to be bold, innovative, and wise in how we invest in the future of America.

I want to thank you, Mr. Chairman, for allowing me to share with you my passion, and that quite simply is the future of our country.

[The prepared statement of Mr. Cernan follows:]

PREPARED STATEMENT OF CAPTAIN EUGENE A. CERNAN, USN (RETIRED),
COMMANDER, APOLLO 17, ASTRONAUT (RETIRED)

Thank you, Mr. Chairman, for inviting me here today to express my personal views concerning the Administration's proposed FY 2011 budget as it pertains to America's role in the future of Human Exploration in Space.

One month ago, Neil Armstrong, Jim Lovell and I released an opinion paper expressing our concern over the Administration's FY 2011 proposed space budget. We spent a great deal of time writing and refining our document, choosing words such as "devastating," "slide to mediocrity," and "third-rate stature" very carefully, so that the intent of our message would not be misinterpreted and our deep concern about the future direction of human spaceflight as outlined in the President's proposal would be fully understood. We particularly wanted to avoid any political overtones because the support of America's role in space since its beginning has traditionally transcended partisan politics.

It was determined after the *Columbia* accident that NASA should return to its core values, focusing its resources once again on space *exploration* while continuing its space *exploitation* through its support of the International Space Station (ISS), with the Space Shuttle providing access to Low Earth Orbit (LEO). The Congress supported such a focus with a near-unanimous bi-partisan support in both the 2005 and 2008 NASA Authorization Acts.

We have recently heard a lot of eloquent verbiage about the *exploration* of space—landing on an asteroid, circling Mars, and at some time in the future perhaps landing on the Red Planet. There is talk about a decision yet to come of building a large booster which might ultimately take us anywhere we want to go into the far reaches of the universe. There are, however, no details, no specific challenge, and no commitment as to where or specifically when this exploration might come to pass. "Hope is not a destination, nor is it a management tool." I, personally, define the *exploration*, in contrast to exploitation, of space as "going where no man has gone before, doing what has never been done before, doing what others couldn't do, wouldn't do, or perhaps were afraid to do."

However, when one examines the FY 2011 budget proposal, nowhere is there to be found one penny allocated to support space exploration. Yes, there has been much rhetoric on transformative technology, heavy lift propulsion research, robotic precursor missions, significant investment in commercial crew and cargo capabilities, pursuit of cross-cutting space technology capabilities, climate change research, aeronautics R&D, and education initiatives. Yet nowhere do we find any mention of the Human Exploration of Space and nowhere do we find a commitment in dollars to support this national endeavor. We (Armstrong, Lovell and myself) have come to the unanimous conclusion that this budget proposal presents no challenges, has no focus, and in fact is a blueprint for a "*mission to nowhere*."

In this proposed budget we find several billions of dollars allotted to developing commercial human access to low-Earth orbit, based upon the assumptions and claims by those competing for this exclusive contract who say that they can achieve this goal in little more than 3 years, and that it can be done for something less than \$5 billion. (These are the same entrepreneurs who are over a year late delivering unmanned cargo to LEO.) This assumes they can design, build, flight test, and develop a man-rated spacecraft and booster architecture along with the infrastructure required for such a venture. This includes redesigning the requirements of mission control, developing the support and training simulators, writing technical manuals for training and onboard procedures, developing the synergy between a worldwide tracking network and the uniqueness of a newly designed space vehicle along with an emergency recovery force needed to handle this new space system. These are just a few of the development and support requirements to put any new manned system into space. Although I strongly support the goals and ideals of commercial access to space, the folks who propose such a limited architecture "*do not yet know what they don't know*." There are a myriad of technical challenges in their future yet to be overcome, safety considerations which cannot be compromised as well as a business plan and investors that they will have to satisfy. As an example, it took over

a year and a half of review and redesign of the Apollo I hatch before operational and safety requirements were satisfied. All this will lead to unplanned delays which will cost the American taxpayer billions of unallocated dollars and lengthen “the gap” from Shuttle retirement to the day we can once again access LEO. Moreover, for a variety of reasons, a “Going Out of Business” sign hanging on the door is always a possibility in any high-dollar—high-risk investment.

The United States, through NASA, has spent a half-century learning what we didn’t know, finding answers to questions we weren’t smart enough to ask at the time, developing technology that was needed to meet the challenge and get the job done. We came from Alan Shepard’s flight in 1961 to the Space Station and Shuttle today with a side trip or two to the moon along the way. The evolution of this learning process was not without its cost—not just in dollars, but also in the lives of our friends and colleagues. It took the courage, effort, dedication and self-sacrifice of thousands of Americans who allowed us to come this far this quickly. And, although we paid dearly for our mistakes, it is a testimonial to their commitment and American ingenuity that everyone who went to the moon came home. Therein is a lesson we cannot afford to ignore. *Is this the NASA we want to transform?*

Based upon my background and experience, I submit to this committee and to the Congress that it will take the private sector as long as 10 years to access LEO safely and cost-effectively. A prominent Russian academician is quoted as saying in order to bring a craft to the standard of quality and safety for piloted flight, the United States will be dependent on Russia until at least 2020. The Aerospace Corporation estimates an initial cost of 10–12 billion dollars, plus the added cost of modifications required to launch vehicle ground systems. Should such a commercial venture run into insurmountable technical problems, business venture concerns, or—*God forbid*—a catastrophic failure, it would leave the United States without a fallback program, unable to access even low-Earth orbit for some indeterminate time to follow. In any event, under this proposal the United States will be abandoning its \$50 billion, 25 year investment in the ISS, leaving us hostage to foreign powers. *Is this one of our “Potential Grand Challenges” of the 21st century?*

Additionally, The President’s proposal suggests we develop “technology for the future.” The technology we enjoy today, 40 years after Apollo, is technology that was developed from accepting a challenge and reaching for a goal. It was technology with a focus, with a mission. To simply put the best and the brightest in a room and tell them to develop breakthrough technology that *could* or *might* or *may* be useful in the future is a naive proposition. Exploration drives *technology innovation—not the reverse*.

Also in the proposal is the *possibility* that *maybe*, at *some time*, *perhaps* as far down the road as 2015, the United States would decide to develop a heavy lift booster. This is a very vague proposition that will likely never be funded to fruition. Coincidentally, Constellation has a heavy lift booster, *Ares V*, not only on the drawing boards but in component test today. Why do we need a new decision in 2015 for one already in development today?

A late addition to the Administration’s proposal, and one very obviously not well thought out, was a provision to build an “Orion Light” spacecraft as a rescue vehicle on the ISS. Although we have never had need for a rescue vehicle, we have today two *Soyuz* continuously stationed on the ISS capable of carrying as many as six people to safety should the need arise, with a provision for a third *Soyuz* should the crew complement ever increase to as many as nine—which is highly unlikely. An “Orion Light,” before it is qualified to transport human beings to safety from the ISS, certainly would have to be man-rated. To man-rate a spacecraft requires a great deal more than following a list of safety requirements and protocol instructions included in its development. The “Orion Light” would have to go through an extensive development, test and evaluation phase before being qualified to carry humans. It sounds very similar to what the existing *Ares I/Orion* development proposal is all about within the overlying Constellation architecture.

Constellation itself is an architecture that over a 5-year period has gone through several detailed reviews and has been vetted by every government agency from the OMB to the DOD, and certainly by NASA—by every agency that has an ownership interest in any technical, scientific, budget or benefit to be derived from Human Space Exploration. In addition, an arsenal of the best engineers, scientists and management experts in America’s aerospace community added their knowledge and expertise to the review of the proposed Constellation architecture before it ever became an official program worthy of consideration. Constellation follows the Von Braun model in the evolution of the *Saturn V*, wherein the development of the *Ares I* is the embryo for the development of the *Ares V*. This shared DNA, with commonality of critical components throughout, leads to greater cost effectiveness, a higher degree of confidence and safety, and provides the first elements of a heavy

lift booster. Appropriately under the law, both Houses of the Congress of the United States with overwhelmingly bipartisan support, approved and agreed that Constellation should go forward.

In contrast to the 5-years which has been required to bring Constellation to its present status, the Augustine Committee was required to provide their report in 90 days. The report contained several suggestions and alternatives to Constellation, few of which were included in the FY 2011 budget, but ultimately the Committee came to the conclusion that Constellation's architecture had been well-managed and is indeed executable, providing it has the appropriate funding that had been denied for several years. Important to note is that the Committee was directed to base their conclusions and recommendations not on the FY 2009 budget, but rather on the FY 2010 budget from which tens of billions of dollars had already been removed between 2010 and 2020. Naturally, the Augustine Committee concluded that Constellation was "unexecutable" within the confines of that budget. I would have reached the same conclusion. More importantly, however, the funding proposed for FY 2011, if prudently administered, is more than adequate to continue the development of Constellation.

It is unknown how much time and thought was put into the existing budget proposal for FY 2011, or by whom this proposal was generated, but it is common knowledge that few if any of those government agencies referred to above were asked to participate, nor, of significant note, was the DOD or the engineering or management expertise that exists throughout NASA today. This leads one to the conclusion that this proposal was most likely formulated in haste within the Office of Management and Budget (OMB) and/or the Office of Science and Technology Policy (OSTP), with little or no input from the NASA Administrator, Center Directors, or senior NASA management. If that were the case, the originators quite likely were promoting their own agenda rather than that of NASA and America's commitment to Human Space Exploration, as directed by Congress in the Authorization Bills of 2005 and 2008.

With the submission of FY 2011 budget, either the Administration and the originators of this budget proposal are showing extreme naivete or, I can only conclude, they are willing to take accountability for a calculated plan to *dismantle* America's leadership in the world of Human Space Exploration. In either case, this proposal is a *travesty* which flows against the grain of over 200 years of our history and, today, against the will of the majority of Americans. The space program has never been an entitlement, it's an investment in the future—an investment in technology, jobs, world respect and leadership, and perhaps most importantly in the inspiration and education of our youth. Those best and brightest minds at NASA and throughout the multitudes of private contractors, large and small, did not join the team to design windmills, but to live their dreams of once again taking us where no man has gone before. If this budget proposal becomes the law of the land, these technicians, engineers, scientists, a generation removed from Apollo, yet re-inspired by the prospect of going back to the moon and on to Mars, will be gone—where I don't know—but gone.

America's human spaceflight program has for a half-century risen above partisan differences from Eisenhower to Kennedy to the present day. The challenges and accomplishments of the past were those of a Nation—never of a political party or of any individual agenda. If we abdicate our leadership in space today, not only is human spaceflight and space exploration at risk, but I believe the future of this country and thus the future of our children and grandchildren as well. Now is the time for wiser heads in the Congress of the United States to prevail. Now is the time to overrule this Administration's pledge to mediocrity. Now is the time to be bold, innovative and wise in how we invest in the future of America.

Thank you, Mr. Chairman, and members of the Committee, for this opportunity to express my personal views on a subject for which I have a passion—the *future of my country!*

The CHAIRMAN. Thank you, sir.
Mr. Augustine?

**STATEMENT OF NORMAN R. AUGUSTINE, CHAIRMAN,
REVIEW OF U.S. HUMAN SPACEFLIGHT PLANS COMMITTEE**

Mr. AUGUSTINE. Mr. Chairman and Senator Hutchison, and members of the Committee, I would like to thank you for permitting me to speak and represent my colleagues on the human

spaceflight plans committee. I have a statement I would like to submit for the record.

I should probably begin by saying that it would be very difficult to gather a group of four people who I admire more or treasure their friendship than the two gentlemen beside me and the two who appeared before us. I think we all share at least one thing in common, and that is that we want a strong human spaceflight exploration program for our Nation.

One might ask why. Our panel tried to answer that and we said that certainly the science to be derived is not unimportant. The same can be said of the economic impact, new products, and certainly engineering achievements have been very significant indeed. But while all of these things are important, it was the view of our committee that taken by themselves they are not sufficient to justify the cost of the human space exploration program.

One has to justify that program, and we think one can justify it based upon intangibles. The fact that they are intangible makes them no less significant in our view. A sound human spaceflight program can blaze a path for humans to move into outer space. It inspires the young people to study science and engineering. We have seen that many of the scientists and engineers were inspired by the two gentlemen beside me and others like them.

But more importantly I think that it says to the world what the American people can accomplish with our system of Government and our system of free enterprise. And all this comes for a little less than a dime a day per citizen, which would seem to be a very great bargain.

Now, one can say a great deal could be done with robots, and that is certainly true—and it should be. But there are certain things that robots cannot do. One thing would be, for example, to make the first repair to the Hubble telescope program. I cannot imagine a robot that could have done that. Similarly, there are the intangibles. Does anyone remember the name of the first robot that stepped on the Moon? Launching a rocket to the top of Everest with a flag in it is quite different from Sir Edmund Hillary climbing to the top of Everest. That is what makes the human spaceflight program so important to so many of us.

I was asked to make a few brief comments on some of the conclusions from the study I chaired 20 years ago on the space program as a whole, some of which perhaps relate to the issue of today. I would cite just five.

The first was, at that time 20 years ago, we concluded that NASA was being asked to accomplish grand goals and being given resources that did not match those goals, and that was a very dangerous thing to do, particularly in space.

Second, reflecting our skepticism of the reliability calculations that were being done, we said it was very likely we would lose another Shuttle. Sadly, that proved to be the case.

We also said that the heavy lift vehicle was the most important project in the human spaceflight program because it is the gateway to outer space. And if one thinks about it, the U.S. has not had an astronaut go much more than 300 miles from the Earth since my colleague here left the Moon years ago.

We thought that the technology program was being starved; that we did not have a strong technology program 20 years ago. And we said that one of the consequences will be that future decision-makers will have very few options.

And finally, we said we need a balanced space program, balanced in terms of human spaceflight and robotics, balanced in exploration and science, and so forth.

Turning to the more recent review of the human spaceflight program that I had the privilege of chairing, we had 10 members on our committee. Our findings were unanimous, as reflected in the 150-some page report that you perhaps have had a chance to read.

The first question is why not just continue the Constellation program. That certainly is the easy, seemingly logical answer. One could do that; but there are some problems. Let me cite just two.

When the Constellation program was begun, now 5 years ago and 4 years from the time we did our study, NASA assumed a budget profile extending some 20 years. In talking to the people who ran NASA at the time, they really believed, I think, that they had good reason to accept that budget profile. But be that as it may, they have received each year only two-thirds of that amount. In other words, it was a one-third shortfall every year. The consequence, coupled with technical problems that the programs have encountered, is that during the 4 years that the *Ares I* program has been going, for example, it slipped somewhere between 3 and 5 years of schedule—depending on whose numbers one chooses to accept.

In addition, we were concerned about the fundamental goal of the program, which was focused on going back to the Moon rather than something more aggressive such as eventually going to Mars with some interesting intermediate stops. Talking to many people, particularly young people, we found that when we said 20 years from now we will be going back to the Moon, most of their response was, “they will have done that 60 years ago.” That led us to be very concerned that our Nation would not be able to maintain the financial support for a program that would require continuous funding from five administrations, nine Congresses, and 18 budget cycles.

Let me turn to the President’s program very briefly, as it was modified in his remarks at Cape Kennedy a few weeks ago. That program fairly closely approximates one of our committee’s options, Option 5B. I should emphasize that we were asked to provide options, not to provide recommendations, so that we could try to be somewhat neutral in this discussion—and we are trying very hard to do that.

The President’s program in our view, at least as reflected in Option 5B—they do differ somewhat—it is considered to be a viable program and we rated it very highly in our overall assessment. We offered two very important caveats. The first is that a vital part of that option is its funding profile, not just the next 5 years but throughout the entire program. And the second is the decisions truly be made on the schedule that they have been planned.

I am sorry to report to you that we, as best as we tried, could find no interesting human space exploration program for a sum of money substantially below the enhanced budget level we described—which, simply stated, adds about \$3 billion a year to the current NASA budget (and that has to be inflated appropriately).

The most important request I would make to this committee on behalf of my colleagues on the Human Spaceflight Committee was that whatever program is approved, that its goals match the budget. Otherwise, I think we will all be back here 10 years from now having this same discussion. It certainly remains the hope of myself and the Committee I had the privilege of serving on that America can have a strong human spaceflight program reflecting the title of our report which is "A Human Spaceflight Program Worthy of a Great Nation."

Thank you very much.

[The prepared statement of Mr. Augustine follows:]

PREPARED STATEMENT OF NORMAN R. AUGUSTINE, CHAIRMAN,
REVIEW OF U.S. HUMAN SPACEFLIGHT PLANS COMMITTEE

Mr. Chairman and members of the Committee, thank you for this opportunity to address America's future human spaceflight plans. I, like you, have had the great good fortune to have lived in this tiny sliver of time when humans first began to explore space, and have had the even greater good fortune to have participated in some small part of that effort as an engineer and as a manager. I must confess to you that I am a proponent of human spaceflight—not so much because of its impact on the economy, its support of science, or its advancements in engineering—although it does all those things—but for the intangibles it offers, including the inspiration it provides to our Nation's citizenry, particularly its young people; for the impact it has in paving the way for humans to move further out into the planetary system; and for what it says to the world about the American people and what we and our system of government and free enterprise can accomplish.

I should note at the outset that it would be difficult to gather a group of colleagues at this table for whom I have greater respect and admiration than those in whose company I find myself today. Nonetheless, as we have all noted, human spaceflight is a topic about which reasonable, caring people can, and do, sometimes disagree. In my opinion such healthy discussion can only help assure, as stated in the title of the report of the Committee I recently chaired, that we have "a human spaceflight program worthy of a great nation."

I have been requested to speak this afternoon from the perspective of the Committee on Human Spaceflight Plans, and to compare its findings and circumstances with those of a similar committee I chaired some twenty years ago. The most recent committee, which has now been formally disbanded, included scientists, engineers, managers, astronauts, professors, and a retired four-star Air Force General Officer. The findings in our report reflect our unanimous views.

I should note that in the case of the most recent study, our group was asked to provide *options* for consideration by the President, Congress and NASA. We were specifically not requested to provide recommendations—presumably so we could adopt a neutral stance in assessing the pros and cons of the various alternatives we might identify and not have to be advocates for any one proposed course. I have tried very hard to be faithful to that charge throughout the recent debate, albeit in some instances that has been impossible; for example, when narrowing the some 3,000 options our committee's methodology identified down to a set of five options offered in our report.

Let me begin with the review that was conducted 20 years ago that addressed the entirety of NASA's space activities, not solely the human spaceflight program as was the case in the more recent review. The earlier assessment was conducted in the shadow of the Challenger failure in which we lost seven of our friends and colleagues. It was also conducted as the Soviet Union—which had provided the impetus for much of America's space activities until that time—was breaking apart. And, while funding for NASA always seems precious, at no time during the space era has NASA found itself in so challenging a budgetary environment as exists today. This of course cannot be ignored.

Some of the relevant findings of that report of twenty years ago have a bearing on the purposes of this hearing today. These included the observations that:

- NASA is being asked to pursue goals that are not matched by the resources that are provided—a hazardous practice in a pursuit as demanding as human spaceflight.

- Based upon our skepticism of the Shuttle reliability calculations, the loss of another Shuttle appears likely.
- Construction of a true heavy-lift launch vehicle is the highest priority for future human spaceflight activities.
- The technology program that underpins spaceflight is being starved, thereby leaving future decision-makers with only limited options.
- America should have a balanced space program, using humans and robots where unique advantages are offered by each.

Turning to the present, the most important finding of the Committee on the Future of Human Spaceflight Plans was that the ongoing program is on an unsustainable trajectory. The reason is straightforward: when NASA began that program, for reasons it presumably believed sound, it predicated the effort on a future budget profile that each year has proven to be fully one-third less than planned. The impact of this has been exacerbated by NASA's very high fixed costs—in some part attributable to the Congress's practice of instructing the Administrator of NASA not to reduce NASA's workforce or facility structure.

The above approach contrasts with that at the end of the Cold War, when the aerospace industry, in pursuit of efficiency, lost 640,000 of its employees and two-thirds of its companies or divisions of companies within a few years. Make no mistake, NASA is the finest space organization in the world with an extraordinarily talented group of people. But it is also a large, mature organization without a strong competitor. At least in the business world that is usually a formula for complacency, not success. The consequences of funding mismatches in such an environment can be severe. For example, the mismatch of ends and means coupled with technical problems that were encountered on the *Ares I* program were such that during its first 4 years the program slipped between 3 and 5 years—depending upon whose schedule estimate is accepted. Further, the heavy-lift vehicle and lunar lander were largely deferred. The question that thus arises with regard to the resulting disconnect among the *Ares I* schedule and that of International Space Station and the planned lunar return becomes not one of *can* the *Ares I* be built, but *should* it?

While the Committee did not offer a program that canceled the Constellation program in its entirety, it did offer an option, referred to in the report as “5B,” that generally approximates the President's plan as it was described during his recent remarks at Cape Kennedy. This program appears to be a viable undertaking, one that ranked highly in our overall assessment . . . provided, and this is to be emphasized, that it is funded as stipulated and that decisions are made as scheduled (especially those regarding a heavy-lift vehicle). The funding profile identified in our report to support Option 5B adds to the baseline budget profile \$3 billion per year, phased in over the next 4 years and realistically corrected for inflation using the appropriate aerospace indices.

While the technical challenges of human spaceflight, especially beyond low-Earth orbit, are immense—the determining factor in defining the program the Nation is to pursue is the amount of funds the Nation wishes to commit to the enterprise. At the higher or “enhanced” budget level the human spaceflight program would cost each citizen about 10 cents per day. Nonetheless, the aggregate sum is undeniably immense.

Try as we might, our committee could find no dynamic, responsible human space exploration program costing less than the program augmented by \$3B per year in inflation-corrected collars. That is not to say there are not important things to be done in space for lesser funds, particularly with robotics, but rather that human spaceflight programs under the more restrained funding profile will necessarily be confined to some 300 miles from the Earth's surface.

Option 5B clearly establishes a human landing on Mars as the primary objective for the human spaceflight program. Unlike Constellation, which sought to reach its initial exploration goal, the Moon, some 20 years in the future, Option 5B follows a path with interim accomplishments including docking with an asteroid; visiting an Earth-Sun Lagrangian point and conducting training operations there; circumnavigating Mars; orbiting Mars; landing on one of Mars' moons, Phobos or Deimos; and eventually landing humans on Mars. A return visit to the Moon is also quite possible, for technical and science reasons; however, it should be noted that our committee received many informal inputs, particularly from young people, questioning why we would have a space program whose centerpiece is something that was accomplished over a half-century earlier. Both China and India have announced plans to land humans on the Moon and it seems unrewarding for the U.S. to participate in a second race to the Moon.

Option 5B, like the President's proposed program, provides for the commercialization of transportation between the Earth and low-Earth-orbit. The reason for this

is that sooner or later NASA must free itself from operating a logistics line to low-Earth-orbit or it will not have the funds needed to meet the grand challenges that await beyond low-Earth-orbit and which NASA and only NASA is equipped to address: namely, the exploration of the solar system.

Our committee's report explicitly states that commercializing transportation to LEO is not without risk. Nothing in space is without risk. But it is the Committee's belief that with *proactive oversight by NASA*, such an approach is feasible and responsible. From a purely business standpoint, we draw the analogy to the Federal Government's guaranteeing a market to carry the mail to the fledgling airlines—an action that made airline travel commercially practicable.

When including this concept in some of the options in our report we noted that all companies, large and small, should be allowed to compete for the market created as just described. We noted that throughout its history NASA has performed the critical role of providing direction and oversight for industry—but it has been industry, not NASA, that has built the overwhelming preponderance of America's space hardware. Further, one wonders what message our government sends in the increasingly competitive global marketplace if it concludes that America's industry is not capable of safely carrying our astronauts into orbit, yet it is comfortable having Russia's industry do so.

I will not seek to repeat the contents of our 154-page report this afternoon. But I would like to conclude with our most strongly held over-arching conviction, and that is that it would be a disservice to NASA and to this Nation to yet again initiate a space program where the means do not match the ends. Doing so merely guarantees that we will be meeting here still another time five to 10 years hence. It is one thing to preserve jobs . . . it is another to conduct a space program. In this case, the former is easy . . . the latter is difficult.

Assuming that this principle of matching goals and resources is embraced, I have the utmost confidence that the extraordinary people of NASA, under Charlie Bolden's exceptional leadership, can successfully carry out whatever program you who lead our Nation may select. And I am hopeful that it will be a program that, as the title of our committee's report states, is "worthy of this great Nation."

Thank you for this opportunity to speak on behalf of my colleagues on the Review of the U.S. Human Spaceflight Plans Committee.

Review of U.S. Human Spaceflight Plans Committee—Members

Mr. Norman R. Augustine
Retired Chairman and CEO
Lockheed Martin Corporation

Dr. Wanda M. Austin
President and Chief Executive Officer
The Aerospace Corporation

Mr. Bohdan I. Bejmuk
Chair, NASA Constellation Standing Review Board

Dr. Leroy Chiao
Former Astronaut, Former International Space
Station Commander and Engineering Consultant

Dr. Christopher F. Chyba
Professor of Astrophysics Sciences and International Affairs
Princeton University

Dr. Edward F. Crawley
Ford Professor of Engineering
Massachusetts Institute of Technology

Mr. Jeffrey K. Greason
Co-founder and Chief Executive Officer
XCOR Aerospace

Dr. Charles F. Kennel
Director and Professor Emeritus
Scripps Institution of Oceanography
University of California, San Diego

General Lester Lyles
United States Air Force (Retired)

Dr. Sally Ride
President and Chief Executive Officer
Imaginary Lines

The CHAIRMAN. Thank you, Mr. Augustine, very much.

I am going to ask the first question.

Captain Cernan, you indicated that we were potentially headed on a journey to nowhere, and I guess I have, in all honesty, to respond by saying that I am not a huge, but I am a substantial skeptic of human spaceflight. We are approximately the same generation, but that is where I am. I cannot support going into space as an end in and of itself. I agree with the President that we need a measured, nationally, globally relevant, and sustainable human spaceflight program, not one solely bound by place and time in space.

But my mind is not closed because I am not an expert. I want to understand the value of human spaceflight.

But I bring one other dimension to it. I want to understand human spaceflight—I am asking this of any of you, not all three of you, but any of you—that it not just be the matter of spaceflight but that it also relate to the human condition not only in the world but also in our own country.

I think NASA was conceived brilliantly with the idea of simply doing something that had never been done before, and we have done it now a number of times. And I do not mean to say by that that we should stop doing it. But I do think we have to stop doing things exactly the same way. I mean, NASA for a number of years has received a lot of criticism over how it has managed its programs. The GAO has not been kind. Various analysts have worried about over-expenditures, things of that sort.

So I want to understand the value of human spaceflight. I want one of you to tell me how NASA's human spaceflight programs advance the agency's overall mission today and in the future. And I also want you to explain how human spaceflight, in that it is in a context of other priorities for NASA, helps the human condition sufficiently to justify its budget in America.

Mr. CERNAN. You are asking for a lot. I will do my best and I will certainly let my colleagues here help me, if they would like.

If you want to talk about technology, technology which you have in your hands today, the technology to communicate around the world, the technology of communications itself, the technology that I have in my iPhone today is technology that was given birth to 30, 40, 50 years ago.

I skipped over my comments about technology that we are talking about in the proposal. Exploration drives technology innovation, not the reverse. You cannot lock a group of the smartest young men and women in the world in a room—engineers, scientists, technicians—and say go develop technology. For what? There has to be a purpose, just like there has to be a purpose in life. They have to know what they are trying to accomplish, what their goal is, what the problems are, and then develop the technology that gets the job done. Going to the Moon. The technology that we developed to go to the Moon. Walk in our hospitals today. Walk in our classrooms today. Is that a benefit to us humans here on this Earth today? I like to think it is. You can go deeper into that, but let me get a little bit more philosophical.

Curiosity is the essence of human existence. Who are we? Where are we? Where do we come from? Where are we going? Is there life

on Mars? Is Mars what Earth is going to look like in a billion years? Are we like what Mars looked like a billion years ago? I do not know. I do not have any answer to those questions. I do not know what is over the hill and around the corner, but I want to find out. It is within our hearts and souls and desire to find out and seek knowledge. Discovery is what it is all about.

And yes, we have been there, but we have not been everywhere. There is a bottom to the ocean. You can walk to the top of the highest mountain on this planet and you can walk to the depths of the deepest ocean, but you are still on Earth. And there is a difference between the frontier of space to seek knowledge. Was there life on Mars? Is there life?

I know there have to be other reasons to go there. That alone is not enough, but that is one of the driving things. It is our destiny, I believe, to explore the unknown, to find answers to the questions, and God knows for every answer we get, we will come up with a dozen more questions. It has been that way all along. We have got more questions about the Moon now than we did before we went there.

So I am probably not being as explicit as you would like me to be, but to the benefits to humans on this planet, whether it is communication satellites, weather satellites, predicting storms, whatever, you can go on and on and on. Those things were given birth to when Kennedy said we are going to go to the Moon. He was asking us to do the impossible. He was asking us to do what most people did not think could be done, and we did not have the technology to do it. That technology is obsolete today in one sense, but American industry, American ingenuity has built upon that so that we have today what we have in our cars, in our airplanes, in our transportation, in every walk of life.

I will turn it over to Neil.

The CHAIRMAN. I cannot. I have overrun my time. I thank you for your answer. It was very helpful.

Senator HUTCHISON?

Senator HUTCHISON. Mr. Chairman, I would just add to what Captain Cernan said and say that is it an improvement of our life on Earth that we can put a satellite-guided missile into a window from 3 miles out and instead of killing 500 civilians, you kill the enemy that you are seeking, is that an improvement? Because that is what has happened because we explored in space.

Let me talk about the future. Dr. Samuel Ting, the Nobel Laureate from MIT, talks about what we can do in the space station in the future to study cosmic rays which are most intense in space, not on Earth, as potentially a future source of energy production. That is the kind of science we are talking about. We are not talking about just going into space to go into space.

I think that is a valid question, and I think you have asked a valid question. If that were all we were doing, I would not be pushing this. I am pushing it because if we continue our priorities in space, we will be the ones that can capture the cosmic rays and have the renewable energy sources that will keep us from having to drill for oil and gas and go to the renewable energy of the future. That is why we are doing this. It is the future, and we want to do it rather than having others do it so that we harness it.

So I want to ask the question because I want to go to something that Dr. Cernan said in his testimony that he did not use because there were so many other things that you did say. And that is talking about putting all of the money into private contractors but having NASA take the step back rather than it being a NASA project with private contractors.

You said that we assume that this goal says that these private contractors that are not yet tested in a little more than 3 years for less than \$5 billion can put people into low-Earth orbit in a new vehicle. It assumes they can design, build, flight test, and develop a man-rated spacecraft and booster architecture, along with the infrastructure required. This includes redesigning the requirements of mission control, developing the support and training simulators, writing technical manuals for training and onboard procedures, and developing the synergy between the tracking network and the uniqueness of a newly designed space vehicle. These are just a few of the development and support requirements to put a new manned system into space.

Basically what you went on to say is that you predict that it will be 10 years, not 3, for the private sector to do this and at a cost which possibly could mean bailing out the companies because we could not really do all of that under \$5 billion.

My question is, do you think that money ought to be spent with NASA redoing their plan so that they are in control, but not just with blinders on as it seemed that General Bolden was saying, "within my budget I can do this." Well, how about being more creative in your budget? How about not doing just Constellation but a new configuration of Constellation? How about an *Orion* that is not just a return vehicle but one that can take people into space as well, but put our money not into termination contracts at \$2.5 billion, not into programs that would try to help people who are going to lose their jobs, not into renting space on *Soyuz*, but into developing our own techniques so that we will gain these advantages? Would that be what you were proposing, Captain Cernan, in your statement?

Mr. CERNAN. Well, referring to what I think you asked at first about all the infrastructure that is needed to support the commercial sector, which is one of the reasons why I think the costs will go way up, as well as the time, the Aerospace Corporation I think did a report that said it would take probably \$10 billion to \$12 billion to support the commercial sector, and it does not count the infrastructure, the simulators, the mission reconfiguration or mission control, the air/sea rescue because it has got to come down. Some of them may come down where you do not want. All the procedures, everything that you have to develop.

A lot of people think that we played handball. When it came time to fly in space, we put on a space suit and jumped into a spacecraft and went to the Moon. We spent years and years helping the engineers at NASA, at Martin, at Rockwell, helping design, develop, test. We were out there 24/7, 6, 8, whatever number of years it took to get the spacecraft that we were going to fly developed properly and safe, that we had confidence in.

So how and when is that going to be prepared for, and what is the commercial sector going to—how are they going to handle that?

How are they going to pay for it? Are we going to subsidize all that? Is it going to be a NASA program or a program that NASA pays for that we let someone else run? Are they going to respond to all our regulatory requirements on safety? These are things that I do not think have been addressed properly yet. I do not think that they have been looked at.

As far as I think what you asked is where I would go, my opinion is probably not worth much these days. But I am concerned in the near term about the gap.

In the long term, I am concerned about exploration because that is my bag. Exploration, going where no man has gone before, doing what has not ever been done before, that others could not do, would not do, or maybe were afraid to do. That is exploration.

But in the near term I know how you feel about Shuttle extension. I do not know anything about the capability to finance it. I think we ought to stretch the Shuttle out and close the gap from the front end. I think we ought to have something that closes the gap on the back end. I do not believe that is commercial space. I believe it is something we have invested \$9 billion in already called *Ares I* and *Orion*. Get it up. Get it running, and instead of a potential gap of a decade, we might knock it down to 3 or 4 or 5 years. I do not know. But at least we will tell the rest of the world that we are not going to stay slave to what they say we can do or cannot do in space. We will have our own access. Even if there is a gap of a few years, we are going to get there from here. Get that done, Senator, and while we are in the process of doing it, if you want to redesign Constellation's long-term exploration objectives and build a new booster or whatever it takes, that is the time to do it.

Senator HUTCHISON. Thank you.

Thank you, Mr. Chairman.

The CHAIRMAN. Senator Nelson?

Senator NELSON. Mr. Chairman, I want to try to answer your question, and it is a good question. I want to thank you for the personal attention that you have given to this hearing being right here the whole time. I am profoundly grateful for that.

My answer to your question, why space, is because we, as Americans, are by nature explorers. We have always had a frontier. When this Nation was developed, we had visionary leaders like Thomas Jefferson who paid initially about \$2,000 for Lewis and Clark to go westward. That trip ended up costing the extraordinary sum of \$36,000, but it was fulfilling our destiny as a people who by nature are explorers and adventurers. And if we ever give up that characteristic, then we are going to be a second-rate Nation. That frontier is no longer westward. That frontier is upward.

And as Gene talked about, we are inquisitive, we are curious. Look what the Hubble space telescope has now opened, the new vistas of knowledge peering back in time to the beginning of the universe. And once we get the James Webb telescope up there, we may be able to go right back to the origin of the universe. Is that valuable to us as an inquisitive people, as citizens of planet Earth? I think it is.

That is my answer to your question.

Now, may I ask a question of Mr. Augustine? Mr. Augustine, it goes without saying. Thank you for your steady hand throughout the years.

You have heard the strong opinions expressed by these two American heroes, and the Committee that you headed contained representatives across the entire spectrum of government and aerospace. And it included military as well, and it included some astronauts.

Now, can you describe how this administration's plan—and you can say how it has been amended as the President amended it down at the Kennedy Space Center—can you describe how it compares with the options that you laid out in your report?

Mr. AUGUSTINE. I would be happy to do that, Senator Nelson.

We had a possibility of up to 3,000 options based on the parameters we looked at. We narrowed them to five main options with a few subsets under several. As I mentioned, Option 5B is fairly close to the one the President has proposed.

There are two potentially significant differences. One is that our option went ahead with the development of the heavy lift launch vehicle right away rather than wait up to 5 years. The other is that we had a funding profile that phased in over 4 years, added \$3 billion per year—and was inflated beyond that with the appropriate aerospace inflator. Thus, our funding profile was substantially greater than the one that we were offered by OMB last year because we could not find a good answer with the OMB profile.

There are advantages to slipping the start of the heavy lift launch vehicle, as you would know. It gives time to accumulate more advanced technology. It helps the early budget pressures when you are trying to keep the space station going, ISS, at the same time—but you would pay the price that you lose time in being able to pursue the exploration program.

I think the biggest risk is when 5 years has passed, or whatever it is, that the program does not restart. And that would be a tragedy in my opinion. That is to me the biggest risk.

The option we offered, 5B, as I say, with those differences is close to the President's program. Assuming that the President's program is fully funded—and I have not seen the out-year funding in any detail, so I cannot testify to that—we found that Option 5B was a rather exciting program. Rather than wait 15–20 years and then land on the Moon, after a few years, it lets you, every few years thereafter, accomplish an objective that you could point to. You can dock with an asteroid. You might even try to move one a little bit. You could go to a Lagrangian point and conduct refueling operations, do maintenance similar to that you might perform on a telescope. You could circumnavigate Mars. You can orbit Mars. You can land on one of Mars' moons, Deimos or Phobos, and from there control robots operating on Mars, which overcomes the huge problem of robotic exploration on Mars, namely, that it can take up to 40 minutes to get a signal back and forth from here to Mars. It offers all of those rather exciting advantages.

That brings me to two other aspects of the President's program that were similar to ours. We did say to shut down the Shuttle, but the only way you could avoid "the gap" is to keep the Shuttle going. The gap was created 5 years ago. That is a fait accompli. If you

want to avoid the gap, the only way I know—and of course, by “the gap,” we refer to being dependent upon the Russians to launch our astronauts to low-Earth orbit—is to use the Shuttle. Our view is it will be a 7-year gap, not a 5-year gap, and we probably better get used to that idea.

If you continue to operate the Shuttle, you can avoid much of the gap, but then the Shuttle consumes all the money you wanted to use to develop whatever is going to replace Constellation or some version of Constellation. Our deliberations kept coming back to how much money you have available, and you get all these tradeoffs that are just very hard to make. If you start a heavy lift launch vehicle now, it is that much less money you have to improve the *Orion*. The one thing that solves the problem is to add \$3 billion a year to NASA’s budget, and I know how difficult that is in today’s environment.

The CHAIRMAN. I want to make one final statement, and then I have to leave.

Senator BROWNBACK. Could I have a—oh, you are going to head out?

The CHAIRMAN. Oh, I am sorry, but I need to do this because I have to leave—

Senator BROWNBACK. I understand.

The CHAIRMAN.—because I was meant to give a speech 10 minutes ago.

What Senator Nelson indicated, the word “exploration,” I agree that is the nature of what Americans have always been. What I think is also worth considering and why I asked in my question to the captain, how human spaceflight contributes to the condition of humankind on this Earth, had another dimension to it. There are various forms of exploration. One is doing the undoable in the physical exploration sense, Lewis and Clark. You two gentlemen, what you did just caught the world. The world’s heart stopped.

But you know, it also stopped but unnoticed in 1876 I think when Thomas Henry Huxley came to open a new medical university called Johns Hopkins, and he said that in the 2,000 years previous to that date, there had been no advances in medicine at all, to wit, during the Civil War and other wars that often diseases were considered to come from outside into the body, which is why powders were constantly being applied to wounds but not necessarily diseases came from inside the body, which we now know to be different. And he did something and Johns Hopkins did something.

In those days, there was no Federal funding for research of any sort. This is 125 years ago. There was no Federal funding for medical research at all. There were no requirements. Harvard had a medical school. Yale had a medical school. Stanford had a medical school. They all had medical schools. You did not even have to have a high school diploma to get into a medical school, much less a college degree. And so they took you and taught you nothing.

What Johns Hopkins did when Thomas Huxley said you follow the truth wherever it takes you in medicine—there can be no compromise on that. You do what you have to do to follow the truth in science, in medicine. And as a result of that, literally the med-

ical education of the United States has been completely revolutionized, and we all understand that now.

Now, that is also—it is not spaceflight, but it is doing the undoable, taking on the unknowable, challenging with no Federal resources—you know, private foundations had to be suddenly activated at this idea of helping medical research. You could read about all of this in a book called *The Great Influenza: The Epic Story of the Deadliest Plague in History* by John Barry. It tells you all about it.

So I just wanted to say in parting, not to rebut anything that has been said, that “exploration” is a broad word. The American search for newness finds many outlets, most of them quite glorious, but not all of them.

I thank you. And Senator Nelson will continue to chair the hearing.

Senator NELSON [presiding]. Senator Brownback?

Senator BROWNBAC. Thank you very much, Mr. Chairman. What a fascinating hearing and great discussion. This is the kind of hearing we ought to have all the time. So thanks, gentlemen.

Norm, why not do what Captain Cernan suggests here? Let us phaseout the Shuttle and use that money to fund and move forward with Constellation. We have spent—what—\$9 billion on Constellation thus far? This is one of the things that drives me nuts, is that we start and stop these space programs all the time. We put \$5 billion in it, and say, oh, well, new administration, let us go somewhere else. I think it drives all folks crazy. But you have noted correctly Constellation was underfunded by a third in this, but why not go the route that Captain Cernan suggested as a way to move forward with Constellation?

Mr. AUGUSTINE. Well, that is a very good question and it is a question we addressed early-on. I have written more articles than I would like to admit over my career about not changing programs, do not start and stop them. If you are going to start them, finish them unless there is a very compelling reason to stop. But in this case, we think there is a very compelling reason.

Yes, it is also very tragic to have to write off \$9 billion or part of it, but it is a sunk cost. It does contribute significantly, we think, to the building of the heavy lift launch vehicle sometime in the future. So part of the money is recoverable.

The real issue comes down to the fact that when the program was started—Really the *Ares I* is at issue here . . . and I say that because the Constellation program, as you know, Senator, has four parts. It has the *Ares I*, the *Orion* capsule, the Altair lunar lander, and the habitat on the Moon. The latter two were not able to be started because the former two ate up the money. So really the existing Constellation Program only has two parts that money has gone into. One part is the *Orion* which, as I understand the President's program, most of that will continue on. So it is really *Ares I* that is at issue.

Ares I was set up by NASA in 2005 with two primary missions. One primary mission was to support the International Space Station, to carry astronauts there. The second was to—really three. The second was to be a part of the space exploration program 15

years from now, and the third was to provide technology and hardware to build a heavy lift version of an *Ares*.

The problem is *Ares I* immediately slipped what our committee believes is 5 years, at least on the plan it was being developed, the International Space Station is going to be back in the ocean by then. And if you add 5 years to the life of the International Space Station, by the time the *Ares* gets developed, it will have maybe 2 years to support the International Space Station. Then subsequent to that, you will have a 15-year hiatus where it will either be the most expensive way in the world to put people in low-Earth orbit or it will be useful for the exploration program. But there is this long down-time.

The Constellation Program perhaps made sense when it started. Today it is not a bad program. The issue is not "can we do it?" but "should we do it?" at least in the form it was laid out.

Senator BROWNBACK. And you do not believe we should do it then?

Mr. AUGUSTINE. To our committee, of the options we looked at—and I am trying hard not to choose sides, it was one of the least attractive options laid out.

Senator BROWNBACK. I am taken by Captain Cernan's comments, which is we do not seem to have a plan now. I mean, we have a lot of ideas floating around, but we do not seem to have a plan. We were working off a plan.

I agree with the low-Earth orbit that we ought to have a commercial sector. Let us try to develop that to go there. But I want a plan to go on, and this one seems to put that off for 5 years. But you just believe that the budgetary numbers are such that even if you took the Shuttle money, you cannot get there with the plan that we were on, and so you are just better off going to something else.

Mr. AUGUSTINE. Yes. It was our conclusion that with the budget that was presented to us, there was really no way, particularly with NASA's very high fixed overhead costs—you and I talked about this—to conduct a human exploration program that would be meaningful and safe.

Senator BROWNBACK. Well, I hope this is the beginning of the discussion, Mr. Chairman. We have had some good thoughts laid out here, but I hope this really now leads into getting the elbow grease on and us really digging into how it is that we move forward on these things.

I thank you for your service, Norm.

And Captain Cernan and Mr. Armstrong, you are just great American heroes, and I really appreciate your willingness to come back and to continue the fight for exploration that you have started and just gave us such an inspiration for and you do not give up on that inspiration. That, to me, is worth a huge amount, even if you cannot measure it. It is that intangible of the exploration that is worth a lot of money for us to do and for future generations.

Thanks, Mr. Chairman.

Senator NELSON. Senator Hutchison?

Senator HUTCHISON. Yes. I want to just say that I have heard the budget was the reason stated for why we cannot keep the Shuttle flying and close the gap. But we are talking about putting \$6

billion into private sector companies, some of which are not developed yet or tested, and then we talk about having to, if they do not make their budgets, bail them out because you have already put \$6 billion in. I would rather talk about what is the best plan and then try to determine the priorities so that you stay within a budget. We should not become wedded to only one way of doing it, but determine what is the right plan to get us where I think all of our goal is, and that is to be able to use the space station and to explore and to assure that we are getting the scientific product that we have already invested \$100 billion in. If we let the space station be in jeopardy of even being useful by not having the backup systems that we control, I do not know that that is good budgeting either. So I have a problem with what I am hearing and the lack of creativity in what we do within the budget that I saw, especially in the first panel.

I would like to ask Mr. Armstrong about the safety issue. In your written statement, you talk about the taxi service that we will be buying from the Russians and the *Soyuz* as being perhaps not necessarily up to the safety standards that we would have on our own Shuttle. Would you talk about the safety issue?

Mr. ARMSTRONG. The prime recommendation of the *Columbia* Accident Investigation Board with respect to new vehicles in the future was that safety be considered the prime consideration. And who can argue with safety? But you cannot put all the money into safety. Safety has to be balanced with program requirements and others. An acceptable level of safety has to be determined. That is what you are really searching for.

We have pretty good confidence on the Shuttle right now. We have had a number of safe flights now ever since the *Columbia*, and it seems to be operating well. Nevertheless, it is a 40-year-old technology, but I do believe that it can continue to be operated safely, as we have in the last few years, and I have a pretty good confidence level on that.

The *Ares I* was projected by outside safety experts to be the safest vehicle that we could project in the future, and it was perhaps two or more times better than all its competitors, including the Shuttle launch vehicle, *Ares V*, and all the expendable combinations.

They did not make a comparison with the commercial entries because they really did not have enough data on those configurations to project an accurate safety value for them.

Senator HUTCHISON. Let me ask you this. Taking the *Soyuz* and the capability that we have to judge its safety over the long term—you know, they are using the same technology, probably 40 years old. But our capability to discern the safety of the *Soyuz* and the new commercial vehicles—do you think that safety would be at a disadvantage with the Shuttle as compared to the new spacecraft that we do not really have tested yet and the *Soyuz*? Do you have any concerns about the safety of the *Soyuz* or our ability to judge the safety of the *Soyuz* for a 7- or 10-year period, which both Mr. Augustine and Captain Cernan have suggested would be the real-timeframe for the gap?

Mr. ARMSTRONG. It is very difficult to project that answer until the commercial vehicles get into the flight environment and are more carefully configured and described in detail.

I think that the *Soyuz*, you know, is clearly a very safe vehicle to return to Earth on.

I think the Shuttle would continue to be safe for some years and we could depend on that. It might take a little extra care but I think it is certainly doable.

I think that the key here on the Ares is that it was designed with the recommendation of the CAIB, but it is safety first. It was designed with that in mind. The commercial vehicles I just do not know what safety considerations they have in their design, but I am certainly hopeful that they are good, but I just do not know.

Senator HUTCHISON. In your testimony you also comment on the *Orion Light*, which has the capability to bring people back off the space station but not go up—and it certainly is not going to have the capability to go to other destinations in low-Earth orbit—as being maybe an expensive project with limited usefulness. Do you think that that is the best use of our budget constraints, to have the *Orion Light* which has that limited capability as opposed to putting the same money into an *Orion* all the way that would be able to do some of the things that really the President said were his goal and which I think are quite exciting, doing an orbit around Mars or some of the other destinations besides the space station?

Mr. ARMSTRONG. No, I do not think it would be a good use of that segment of the funds in the budget. I think not because it would be quite an expensive vehicle to design and test, and it would be quite late before it would be ready and it would not be able to service the space station very long after it was finally completed.

And second, the configuration is probably not very good for some of the most serious emergencies like a medical emergency where you have to have instantaneous departure from the space station and return to Earth because the aerodynamic configuration of an *Orion*-type vehicle has poor aerodynamic performance and consequently cannot change its destination and arrive quickly at some point. It is going to come down in the ocean or on land, wherever it comes down, if it is an immediate emergency departure.

Mr. CERNAN. May I add something to that, Senator?

Senator HUTCHISON. Sure.

Mr. CERNAN. We already have under contract two *Soyuz* up there for rescue with the capability to put a third up there. So the redundancy or the reason for an *Orion* light just puzzles me, plus the fact the *Soyuz* lands on land, parachute, retro-rockets and so forth, in our own landing facility. The Shuttle lands on a runway. Now we are going to have a ballistic or maybe slightly lift capability spacecraft very much like Apollo, and it is going to have to land in an ocean. Now we have got to regenerate the recovery forces.

See, it is just not the cost of man-rating that vehicle which has to have men in it before you can put—and I use the term generically. Before you can put men or humans in it to bring them home safely, you have got to man-rate it to start with. And then you must have the recovery forces standing by somewhere, some aircraft carrier within reach somewhere, that is going to have to recover the spacecraft, a cost nobody seems to recognize or acknowl-

edge. There is a lot of hidden, underlying cost in developing a spacecraft that is going, as you said earlier, to have half the capability of the one we really need.

You know, if I may, we talk about budgets and cost of everything, and I want to remind the American people out there and maybe even some people in Congress that it costs little more than a half a penny of every tax dollar that you and I send to the Federal Government to pay for the Space Shuttle, space station, Hubble, Opportunity and Spirit on Mars—little more than a half a penny. I do not think the American people know that. I am not sure if we did not put a little box on that 1040 and said, would you give a penny to NASA, that we would not be able to afford almost everything we want to do.

Senator HUTCHISON. Well, I think that people would believe that the investment that we have made has improved the quality of life and health. The MRIs that people can get now, the magnetic resonance imaging, has transformed health care. There are so many things that space exploration—the preparation for it has given us in quality of life. I just want to make sure that we do not lose that advantage and the capability to manufacture those products in America for the quality of life in America and the world.

We do have a vote. So I will close my part and thank you all very, very much for coming and for being so direct especially because we have to speak out and try to come together in a better plan than has been put forward so far. And I think General Bolden is going to try to work with us to see if we can come to a plan that everyone can feel is the right approach for America and for our future both economically and for the scientific productivity that we hope to encourage our children to pursue.

Thank you, Mr. Chairman.

Senator NELSON. Mr. Augustine, did your commission determine that Ares would be much safer than the existing Shuttle, and if I recall, was it by a factor of 10?

Mr. AUGUSTINE. I must confess I find myself a little bit in the situation of Neil, until you build this hardware. Our committee is very skeptical of the reliability and the safety models. Most of the failures we have encountered are not even in the models, so I would be reluctant to make a comparison. As Gene has pointed out, the *Ares I* was designed specifically with safety and reliability in mind which should bode well in that regard.

But by the same token—and I would like to say this about the commercial launch vehicles, if I might, Senator, although it was not your question, I think there are two things that have not come up in this conversation. One is that NASA, in the plan that has been put forth, would have responsibility to oversee safety and reliability for the commercial launchers. In other words, that part of it is NASA's responsibility to oversee. General Bolden understands that.

The other comment is in talking about the commercial launch companies we tend to talk only about startup companies. Our option said that anybody who wants to bid, the big companies, the old companies, the Boeings, the Lockheed Martins, as well as the new start-ups, can bid. Regarding feasibility, one of the commercial

companies, the larger companies, has a launch vehicle that in all its versions I think has over 90 straight successes now.

I would like to make one other comment in that regard, if I might, just to put things in perspective. We tend to think that it is a big jump for industry to get to a really safe launch vehicle, and I do not want to understate the difficulty of this. There is risk here. There is risk anywhere in space. I was thinking, as we talked, again in terms of the advancement of technology over time and how much industry must have progressed since these gentlemen went to the Moon. The time from the Wright brother's flight until Neil and Buzz went to the Moon is just about the same elapsed time as it will be from the time they left the Moon until we return to the Moon under the plan in place. It offers kind of an interesting perspective.

Mr. CERNAN. Disappointing.

Mr. AUGUSTINE. Disappointing.

Senator NELSON. Mr. Armstrong, you made the case in your prepared statement—and by the way, we will insert in the record Jim Lovell's prepared testimony. That will be a part of the record.

[The prepared statement of Mr. Lovell follows:]

PREPARED STATEMENT OF CAPTAIN JAMES A. LOVELL, USN (RET.),
COMMANDER, APOLLO 13

I apologize that I cannot attend your hearing with my fellow astronauts, Neil Armstrong and Gene Cernan. I do want to submit this written testimony to establish my position with regards to the NASA 2011 budget.

As I celebrated the 40th anniversary of the Flight of Apollo 13, I also realized I was witnessing the end of an era. It was an era that started in the late 1950s when bold leaders decided to make America a leader in space technology. Projects were formulated and technology developed resulting in missions completed: Mercury, Gemini, Apollo, Skylab, Space Station including over 130 flights of the Shuttle. That era will end with the last Shuttle flights by the end of this year.

In 2004, as a result of the *Columbia* accident, it was decided that a bold new approach to America's space exploration was needed. A program that would reach out to the moon and beyond. President Bush launched his "Vision for Space Exploration" to outline a project providing the means to continue America's prominence in space exploration and capture the imagination of its citizens.

NASA initiated the "Exploration Systems Architecture Study" to determine the most cost effective way to provide continuous support of the ISS while fulfilling NASA's mission for deep space exploration.

The resulting Constellation architecture envisioned two basic elements. The ARES 1 first to be a LEO vehicle and then be added to the *Ares V* for deep space missions.

This vision for space exploration, and the NASA Authorization Acts of 2005 and 2008 was, over the years, endorsed by two Presidents of different parties and approved by both Democratic and Republican Congress.

The Constellation Project was a program of much greater magnitude than any previous endeavor. It envisioned considerable exploration of the Moon:

1. To gain experience and confidence in deep space operations.
2. To develop the infrastructure necessary for considerable length of stay and area of exploration in anticipation of a future Mars expedition.
3. To regain our prominence in lunar operations in anticipation of other countries spaceflight activities.

The failure of the past Administration to adequately fund the Constellation Program resulted in a slowdown of *Ares I* development putting the United States in jeopardy of not having access to the Space Station.

When the President Obama canceled the Constellation Program, that eliminated progress on the *Ares I* for LEO operation and signaled the end of American dominance in space exploration. After years and billions of dollars to develop the ARES family of vehicles to serve LEO and outer space we have abandoned the dream of President Kennedy. And, as the *Columbia* Accident Investigation Board noted "the

failure to develop a replacement for the Space Shuttle program represented a failure in national leadership.”

In some respects the Vision for Space Exploration which the Constellation Program was part is similar to Project Apollo. On announcing Apollo, Kennedy said “this goal will serve to organize and measure the best of our energies and skills.”

The 2011 NASA budget has taken NASA’s mission on a new path. Recent pronouncements from NASA’s Deputy Administrator revealed that NASA’s goals are to relieve hunger and poverty, create world peace, improve education and the environment and create new jobs. As noted by Congressman Bob Bishop, NASA was established to explore space.

NASA wasn’t created as a “make work” program but it did provide jobs for thousands of people in the private sector.

NASA’s main focus is not on education. But it was a spur to education for thousands of youngsters. Children now in their late 40s or 50s who were inspired by our space activities.

NASA wasn’t established to revitalize business and industry but the manned program resulted in thousands of technical spin-offs from NASA development have helped the private sector unrelated to space activities.

NASA was not meant to be a foreign relation tool but the space agency did bring close cooperation with countries through the development of the ISS.

President Obama’s remarks at KSC concerning the future of America’s Manned Space Flight talked about ground breaking technologies to enhance spaceflight including research on a “heavy lift rocket”. But his speech did not lay out a plan on how this technology will be used or who would use it. In the past, goals were first defined *i.e.*, Mercury, Gemini, Apollo and then the technology was developed to accomplish the objective.

The President mentioned subsidizing the development of commercial LEO vehicles to service the space station. In the past the private sector did design and build launch vehicles under government contract but NASA supervised their construction and flew them.

Commercial space taxis are a possibility but is there a market for them? Between 2008 to 2010 there will be only 10 Shuttle flights to the ISS.

Will these launch vehicles be “manned rated” with private money or will a massive infusion of government funds be necessary to make them ready for manned flight? If that is the case, the billions of dollars and time spent on *Ares I* will be lost as new launch vehicles to LEO are developed.

The only access to the ISS after 2010 is by means of a Russian spacecraft. China and India have already developed launch vehicles that will allow entry into low-Earth orbit. In the future they could request entry into the ISS thereby extending its life. We must remember that the ISS overflies the United States. From a security standpoint, continuing *Ares I* development was the quickest way to reestablish our own entry to the ISS.

The general thrust of the President’s talk at KSC was to place NASA in a support role similar to its previous life: National Advisory Committee for Aeronautics. But NACA supported a viable entrepreneurial aviation industry. There are no commercial prospects for deep space exploration. Congress established NASA to pursue that objective.

This Congress has to make a bipartisan decision whether to realign the NASA 2011 Budget to maintain the United States a leader in the exploration of space as outlined by the Constellation Program or forgo the prestige and respect we now enjoy from the rest of the world.

Senator NELSON. You made the statement that we ought to go back to the Moon, and I want you to tell us why you think returning to the surface of the Moon is important as opposed to a lunar fly-by and going to Lagrangian points as we ultimately have the destination to go to Mars.

Mr. ARMSTRONG. Thank you, Mr. Chairman.

I do believe that there is value in returning to the Moon. We know a thousand times more about the Moon than before Apollo, but there is still so much of it that is undiscovered and unventured upon. There may be valuable minerals or other materials in the lunar surface that can be used at such time as when permanent settlements will be made there. It is worthwhile knowing about those things. So I do think there is value in going to the surface.

Nevertheless, there is also value in using the Moon as a location from which you do other activities, either Lagrangian points or other positions at lunar distance that can be reached easily by communication with only a second and a half time lag and allows mission control to continue to be involved in the efficiency and safety of the operation. We can learn in the lunar regions many of the things that are still unknown or undeveloped in our current state of knowledge about interplanetary space travel, particularly things like radiation protection and so on, where we have the possibility to get out of real trouble when we get in it because we are so close to home back to Earth. That is a possibility that we will not have once we find ourselves months away from Earth. So consequently, I think there is great value in continuing to include Moon as an integral part of the space exploration program as we go forward.

Senator NELSON. OK. And I will just close by saying that Mr. Augustine said that they deliberated this on the panel, and they pointed out that one of the things you have to sustain is the support from the American people. What the Chairman of the Augustine Commission wanted to do was to get that excitement returned. And there was a legitimate question raised: Can you get by going back to the Moon? And perhaps you can if we know what our goal is. Now, the President has stated that goal.

Now, let us see if we can achieve it.

Thank you all very much. The meeting is adjourned.

[Whereupon, at 5:41 p.m., the hearing was adjourned.]

A P P E N D I X

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. KAY BAILEY HUTCHISON TO
HON. CHARLES F. BOLDEN, JR.

Question 1. General, in conversations before this hearing with me and with several of my staff members, you indicated that you had available a detailed analysis that outlined the anticipated servicing requirements for maintaining and sustaining the International Space Station (ISS) through at least the year 2020, and that you would provide that documentation very shortly to me and my staff. I would like that information to be made a part of the record of this hearing, and so I reiterate a request that you provide the following:

- a. An in-depth assessment of all essential modules, operational systems and components, structural elements, and permanent scientific equipment on board or planned for delivery and installation aboard the International Space Station, including both United States and international partner elements, to determine anticipated spare or replacement requirements to ensure complete, effective, and safe function and full scientific utilization of the ISS.
- b. The identification of spare or replacement elements and parts currently produced, in inventory, or on order, and the state of readiness and schedule for delivery to the ISS, including the planned transportation means for such delivery. Each element identified shall include a description of its location, function, criticality for system integrity, and specifications regarding size, weight, and necessary configuration for launch and delivery.
- c. The identification of anticipated requirements for spare or replacement elements not currently in inventory or on order, a description of their location, function, criticality for system integrity, the anticipated cost and schedule for design, procurement, manufacture and delivery, and specifications regarding size, weight, and necessary configuration for launch and delivery, including launch vehicles known to be available and capable of transportation of such items to the International Space Station, in the event planned or proposed transportation systems may not become available at all, or on a timely basis in order to meet anticipated need-dates for delivery to the ISS.
- d. For all the above information, provide a summary of the basis for the determinations made, including a description for the underlying data, including, but not limited to, on-orbit analysis of failure rate experience to date aboard ISS, compared to manufacturing assumptions, requirements and certifications lifecycle expectations. Also include any description of evolution of maintenance plans requiring return to Earth for failure analysis, refurbishment, remanufacture, and return to ISS, versus alternate or current plans for on-orbit repair or disposal.

Answer. NASA has processes in place to continually plan for the operation of the ISS, and to adjust logistics resupply as required due to onboard failures, new issues that arise, or systems operating longer without failure than initially predicted. At a strategic level, the Agency plans for the delivery of cargo to the ISS by a mixed fleet of vehicles, and finalizes detailed manifests closer to the time of flight. Therefore, it is not possible to provide the level of detail requested for every piece of equipment to be launched to the ISS through 2020.

However, in response to requests for detailed information about current ISS parts inventory and NASA's plans for delivering components to the Station and ensuring its sustainability to 2020, the Agency has provided to Committee staff the following information:

- A listing of the remaining items to be flown aboard the Space Shuttle; this list covers science payloads to be flown as part of the Shuttle missions, as well as those to be taken to, or returned from ISS during Shuttle missions.

- A preliminary manifest (MIM Rev K Strategic Flight Plan), showing cargo and crew launches to ISS from March 2011 through November 2014. This manifest shows the associated Orbital Replacement Units (ORUs) on the different vehicles. In some cases, allocations are to be determined based on the timeframe, and smaller ORUs are not necessarily tracked at this level—they in turn are manifested much closer to their respective launches.
- A detailed listing of ISS spares warehoused at Kennedy Space Center, including part numbers, quantity, criticality code (a description of the codes was also provided), and description/function of each item. Except for the Blanket and Box-L, Blanket and Box-R, and the HRS Radiator, all other ORUs are available to fly on Commercial Resupply Services (CRS) vehicles. Where they are ultimately manifested will be based on replacement needs on orbit. The only ORU in inventory that can only be flown in the Shuttle is the HRS Radiator. All other large spares that require Shuttle to deliver will be pre-positioned on ISS by Shuttle retirement.
- A schematic of the ISS showing the External Orbital Replacement Unit (ORU) Pre-Positioning Architecture, indicating the 71 ORUs which will be pre-positioned in ten locations around ISS as of January 2012.
- A chart showing current projections of ISS requirements versus cargo resupply capability from 2011 through 2020. This chart provides projected metric tonnage to be delivered by year, by vehicle type, including current and potential future Commercial Resupply Services (CRS) providers, as well as International Partner vehicles. Requirements are broken out by crew supplies, water, and gas; maintenance. Extravehicular Activity (EVA) demand; baseline utilization; and, contingency maintenance, potential research opportunities.
- A briefing by the Associate Administrator for the Space Operations Mission Directorate on sustaining ISS operations through 2020 after the Space Shuttle is retired. Topics covered included internal and external spares strategy; post-Shuttle launch capability, including the flexibility to accommodate delays in the availability of CRS vehicles; sparing plans for different Station systems (e.g., batteries, carbon dioxide removal systems, oxygen generation); and, water inventory and propellant requirements.

Question 2. The 2008 Act required a report, within 120 days of enactment (October 15, 2009) of what would be necessary to sustain the ISS vehicle and systems through at least 2020. A report was finally received on August 7th, 2009. It provided information that was not particularly helpful and contained a number of contradictory items—descriptions of critical systems for which analysis would be made in 2011—AFTER the planned end of Shuttle operations—for systems that appear unlikely to be able to be transported to the ISS on any vehicle other than the Shuttle. In most cases, reliance for delivery was placed on “planned” availability of COTS cargo capability, because the additional cargo-delivery systems, the Russian Progress vehicle, the Japanese HTV and the European ATV, would still leave a short-fall of 40 metric tons of required supplies. There was no indication of the impact of a failure of either the COTS cargo capability or the ATV and HTV systems, neither of which had flown to the ISS at that stage. Can you explain why this situation and response by NASA should inspire confidence that the needs of ISS sustainability are either a) fully understood and considered, or b) considered to be a serious defect in contingency planning to ensure ISS sustainability?

Answer. Pursuant to Section 601 of NASA Authorization Act of 2008 (P.L. 110-422), the NASA report, “Plan to Support Operations and Utilization of the International Space Station Beyond FY 2015,” noted that after the retirement of the Space Shuttle, the International Space Station (ISS) will be maintained by U.S. commercial cargo resupply systems and the International Partners’ vehicles. This provides the Program with redundant systems for Station replenishment, in case there is a failure of a particular vehicle. The report described NASA’s assessment of the major ISS systems and their viability beyond 2015, projected upmass and downmass requirements through 2020, and noted strategies to mitigate downmass constraints. As NASA and its partners continue to gain experience with the ISS, which has already been continuously crewed for almost 10 years, the sustainability assessments will be further honed. It is important to note that, with the exception of the HRS Radiator spare, all ISS spares that have not been prepositioned on orbit before the retirement of the Shuttle can be flown on other vehicles. Thus, in addition to having critical prepositioned spares on orbit, the Program will be able to fly ground-based spares to ISS, as needed.

Question 3. I should note that NASA was asked—at the urging of myself and other Members to the Augustine panel—to provide similar information to that Re-

view of Human Space Flight plans. That submission was, in fact, more responsive and informative than the identical summary provided to the Congress, in roughly the same time period. The difference was, that the submission to the Augustine panel was considered an internal communication and did not require review—and amendment—by OMB. We have both submissions, and the comparison is dramatic. The same is true regarding the report required by the 2008 Act regarding options for extending Space Shuttle flights. The NASA submission to the Augustine panel was much more informative—and in fact, I believe formed the basis for the fact that Shuttle extension to 2015 was one of the options put forward by the Augustine panel in its final report. Is this an indication that, when the Congress requests information from NASA, the factual programmatic expert response of the NASA engineering and program managers is, in effect, diverted by OMB in a way that deprives the Congress of the accurate and complete information we need to make informed decisions?

Answer. All NASA reports to Congress, including the “Plan to Support Operations and Utilization of the International Space Station Beyond FY 2015” and the “Impacts of Shuttle Extension,” are written to respond to the particular Congressional reporting requirement. The Agency endeavors to provide accurate and complete information in these reports, which are written with technical inputs from cognizant Agency personnel and vetted within the Administration to ensure consistency with policy.

Question 3a. How do you respond to the fact that, at this point in time, we simply do not know, with any degree of certainty, that there may be essential components without which the full functionality—or even survivability—of the ISS can be assured, which would require the capacity of the Space Shuttle to be able to deliver?

Answer. Please see the NASA response to *Question Number 2*, above. With the exception of the HRS Radiator spare, all ISS spares that have not been prepositioned on orbit before the retirement of the Shuttle can be flown on other vehicles.

Question 4. Let me turn to the new plan announced by the President to revive the *Orion* Crew Exploration Vehicle that is part of the canceled Constellation Program, but in a design modification that would allow it to be launched unmanned on an expendable launch vehicle, to serve as a life-boat for the ISS. How is that development going to be paid for, and what is your estimate for the cost and the schedule for delivery to the ISS?

Answer. NASA and the White House look forward to working with Congress to develop a plan that balances a restructured *Orion* project with the other priorities in NASA's FY 2011 budget. All of the pending appropriations and authorization bills match the President's top-line request for NASA, so any costs for a restructured *Orion* would need to be offset by reductions to other line-items.

Question 4a. How many such vehicles would be required? Would they be cycled every 6 months, like the *Soyuz* vehicles, or would they have a longer on-orbit stay-time?

Answer. A NASA study team that is developing plans for an emergency return vehicle is assuming a goal of at least a 3-year life on the ISS, and is assessing the technical details and costs associated with achieving this goal.

Question 4b. How many seats would they provide? Would they enable the four seats that the United States is still obligated to provide under the Memoranda of Understanding and Intergovernmental Agreements for ISS signed in 1998?

Answer. The emergency return vehicle study team assumed a requirement to return up to four crew members. This is consistent with the capabilities of the most current design for *Orion's* ISS mission version.

Question 4c. Would that mean that the total crew size could be expanded to seven, as originally planned, thus enabling greater potential for crew time being applied to research, as opposed to ISS maintenance? If so, how would that impact the models for cargo and supply requirements?

Answer. The plan for the emergency return vehicle would limit the use of the spacecraft to an emergency crew return capability. This would enable the return of up to four astronauts at a time, but since the vehicle would be launched uncrewed to the ISS, the Expedition crew size would be constrained to six by the use of two *Soyuz* spacecraft at a time for transportation to and from the Station.

Question 4d. Given the three-seat limitations on *Soyuz*, would that make it impossible to expand the crew size because of no way to deliver the sufficient number of crews to ISS? If so, what is the advantage of developing and using the *Orion* as a crew-rescue vehicle only?

Answer. Please see the NASA response to *Question Number 4d*, above. The development and use of the emergency return vehicle would provide a redundant rescue capability that would complement that of *Soyuz* and enable the ISS program to move away from “single string” dependency in that area. In addition, an emergency return vehicle could serve as the basis for further development of spacecraft technology for exploration.

Question 4e. How would the cost of development and launch of the *Orion* CRV compare to the cost of simply continuing to pay for Russian *Soyuz* to serve the crew escape function?

Answer. NASA is still assessing the costs of developing, launching, and operating an *Orion* emergency return vehicle.

Question 5. In the 2005 NASA Authorization Act, signed into law as Public Law 109–155, the Congress stated that it was “the policy of the United States to possess the capability for human access to space on a continuous basis.” The law went on to make it clear that such capability for human access to space on a continuous basis was to be provided by U.S. transportation systems, not by other nations’ capabilities that we would “rent” or purchase access from. It is also a matter of international agreement, within the ISS implementing agreements, that the U.S. would be responsible for providing access to the ISS for European, Japanese, and Canadian crew members. The decision to terminate Space Shuttle operations in 2010, at least 4 years before any replacement U.S. capability was then planned to be available, was a direct violation of both the spirit and the letter of that law. When you and your Deputy Administrator each took the oath of office as Administrator, after confirmation by the Senate, you both swore to uphold the laws of the United States. What have you done, since assuming your positions, to ensure that the law of the United States, establishing a policy of continuous U.S. capability for human spaceflight, is upheld?

Answer. As noted in the above response the “gap” in U.S. human spaceflight capability was the result NASA not having sufficient resources to simultaneously fund continuing Shuttle operations while developing the next generation U.S. human spaceflight program. The fact of the gap has been long established; the questions have been how long the gap would last, and what domestic system(s) the U.S. would use in the future. The new direction for the Agency aims to minimize this period by encouraging a robust commercial space industry in LEO that can provide crew transportation services to the U.S. and its European, Japanese, and Canadian ISS partners.

Question 5a. If a proposal by the Administration—whether the Obama Administration or the Bush Administration, created and imposed on NASA by the Office of Management and Budget, or by the Office of Science and Technology Policy—represents a direct circumvention of the law, what is your responsibility, as the Administrator of the agency empowered to implement that law, to take steps to inform the authors of that proposal that their actions are in violation of the law, and to insist that they adhere to the law and policy established by the Congress?

Answer. It is the responsibility of everyone in public service to uphold the laws of the United States, and to ensure that proposals they advocate adhere to the law. In April 2009, NASA submitted to the Congress its Human Space Flight Capabilities report, which responded to language in Section 611(a) of the NASA Authorization Act of 2008 (P.L. 110–422) directing NASA to report on the lack of a U.S. human spaceflight system to replace the Space Shuttle upon its planned retirement. This requirement was an amendment to a reporting requirement in Section 501 of the NASA Authorization Act of 2005 (P.L. 109–115), referenced above. This report was required by law in case it was determined that the U.S. would not be able to maintain the capability for human access to space on a continuous basis.

Question 6. The Statement of Work defined in the 2008 Request for Proposal for the Cargo Resupply Services contracts, issued to both SpaceX and Orbital Sciences Corporations, indicate a requirement (page 159) for delivery to the ISS during Calendar Year 2010 of 2.7 Metric Tons of Internal Upmass, and one-half metric ton of return down-mass and 1.5 metric ton of disposal downmass. Have these requirements been modified under the CRS contracts? If not, can you provide:

The current schedule for which compliance with these requirements are anticipated.

Answer. The Statement of Work provided the initial requirements for the service providers to bid against. After contract award, actual upmass requirements and launch dates are negotiated with each provider and are baselined through the Vehicle Baseline Review for each mission. NASA and SpaceX have baselined the first three commercial cargo missions.

- SpaceX CRS I September 2011 (tentative)
- SpaceX CRS 2 October 2011
- SpaceX CRS3 June 2012

NASA is in the process of baselining the first Orbital Sciences Corporation commercial cargo mission through the Vehicle Baseline Review process.

Question 6a. Whether alternative means have been identified for delivery and return of the specified amounts of material.

Answer. The initial cargo manifest for any first cargo mission to the ISS is limited to low priority items. Initial Statement Of Work requirements for cargo in 2010 have been redistributed between the remaining Shuttle missions and International Partner vehicles.

Question 6b. Any impact to ISS provisioning and operations resulting from a failure to meet these requirements.

Answer. In the event of slips to the schedule for Commercial Resupply Services (CRS) flights, on-orbit spares that have been pre-positioned will be employed to the extent necessary. Since requirements for component removal and replacement are a function of failure rates, this cannot be predicted with the precision requested. The pre-positioning strategy for spares and consumables, as well as the cargo capacity and flexibility available on Automated Transfer Vehicle (ATV), H-II Transfer Vehicle (and Progress missions, ensures that any impacts to ISS operations and maintenance will be minimal during this period.

Question 7. From the standpoint of relatively near-term human spaceflight, the President's proposed budget and associated plan seem focused on: (a) The development of a commercial, as opposed to government-owned human spaceflight launch capability and (b) The continuation—and expansion—of support to the International Space Station to at least 2020. Would you agree with me that, in actual fact, the two initiatives are directly interwoven, in that the real driver behind the business case for commercial space launch capability—for both cargo, as under the COTS program now underway, and for human spaceflight, at least in its early stages—is the existence of a viable, healthy, safe and functioning International Space Station?

Answer. The decision to extend the International Space Station (ISS) likely to 2020 or beyond provided a real, sustainable, and relatively long-term base market for commercial human space transportation services. In the near-term, NASA hopes to be a reliable customer for human space transportation services for U.S. and U.S.-designated astronauts for the ISS. Longer term, NASA hopes that this initiative will enable the eventual development of a robust, vibrant, profit-making commercial enterprise with many providers and a wide range of private and public users.

Question 8. As you begin to develop the requirements for a competition for a commercial crew development contract, what would be the target date for full operational capability, and how would you define that?

Answer. NASA's current planning reflects development flight demonstrations in 2014 and 2015, with the start of services flights in 2016. NASA has not yet established agreed-to terms for Initial Operational Capability and Full Operational Capability. Those terms will be established with individual partners during the negotiation process.

Question 8a. What is your best estimate for when a commercial crew launch system might be fully operational?

Answer. The start of services flights would coincide with the system being "fully operational," *i.e.*, our estimate is 2016.

Question 9. Estimates I have heard, range from operational capability within 3 years of the start of development, to as many as 5 or even 7 years. That would mean 2014 at the earliest, if you start in 2011, for which this budget is proposed, and as late as 2016 or 2018. In the meantime—assuming the end of Shuttle operations 6 months from now—for that 4 to 6 or 7 year period, the only vehicle available to carry any crew members to or from the ISS is the Russian *Soyuz*. (Let's assume, for the moment, that the newly-proposed *Orion*-derived Crew Rescue vehicle is not going to be available for most of that same period of time.)

What would happen, General Bolden, if there were an accident with the *Soyuz*, either with the launch vehicle on ascent or the crew module on descent, which were serious enough to ground the *Soyuz* for an extended period of time while an accident investigation were completed and any necessary changes made?

Answer. If an accident were to happen that would ground the *Soyuz* launch vehicle and crew module, NASA, along with its partners, would evaluate the risk to ISS operations including the state of the on-board Expedition crew. The safety of the on-

board *Soyuz* spacecraft would be evaluated based on the particular failure. It is possible to make certain modifications to the *Soyuz* spacecraft on-orbit if necessary.

Furthermore, the *Soyuz* spacecraft is a very robust system as demonstrated by anomalies experienced during descent in 2007 and 2008, which were subsequently reviewed and resolved. If it were determined that the onboard crew would be required to stay on-orbit beyond their certified Expedition period, it would be possible to extend the certification of the crew and spacecraft systems.

In any case, NASA does not believe that there is any scenario related to a *Soyuz* accident that would require the immediate de-crewing of the ISS after a *Soyuz* accident. Any actions taken by NASA would be coordinated with the ISS Partners as well as with Congress and the White House.

Question 9a. How long would it be before the six-person crew still aboard the ISS would have to evacuate—using, I would point out, two of the very same kind of vehicles which just experienced a critical failure, assuming the failure occurred on descent?

Answer. See NASA response to *Question Number 9* above. It should also be noted that any need to de-crew the ISS is directly related to the consumable stores onboard, health of the crew, health of the ISS, and the health of the spacecraft. This is a dynamic situation that requires in-depth analysis based on the constraining parameters at the time of occurrence.

Question 10. If, in this scenario, the ISS crew had to abandon ship, how long could the untended ISS remain viable in a minimal state of ground-controlled automated activity, before its orbit might deteriorate or systems might begin to fail without crew maintenance, to the point it would be irretrievable or impossible to reactivate once the *Soyuz* were able to fly again?

Answer. NASA has plans and procedures in place for the crew to take necessary measures to configure the ISS platform in order to maintain safe untended operations for an extended period. Among the tasks the crew would perform would be to configure the ISS for a minimum power usage and close all hatches. The ISS systems that are needed to maintain a stable and viable vehicle are robust in their ability to perform even after failures and anomalies. Key systems such as the electrical power system; guidance, navigation and control; communications; and, active propulsion have multiple layers of redundancy. The ISS would also be boosted to a higher orbit to maintain altitude, defer re-entry, and allow time for thorough analysis of recovery options.

Question 11. Given the seriousness of this very plausible and possible scenario, it is of great concern to me that answers to these questions are not clearly available and have not been fully addressed before the decision was made to launch the country on this path for human spaceflight. Can you explain why these contingencies have not been fully—and satisfactorily—addressed BEFORE the FY 2011 budget and the new plan for human spaceflight was adopted by the Administration?

Answer. The reliance of the ISS partners on a single crew transportation system (*Soyuz*) for a period of time between the retirement of the Space Shuttle and the development of a follow-on system was established years ago when it was determined to retire the Shuttle at the completion of ISS assembly. NASA cannot simultaneously fund continuing Shuttle operations while developing the next generation U.S. human spaceflight program, so a period of “single-string” reliance on *Soyuz* was unavoidable. NASA has been working with its Partners to ensure that the ISS is functionally and operationally robust in performance and in spares provisioning in order to mitigate any risk from a potential grounding of the *Soyuz* fleet. NASA believes that the plans it has put in place with the ISS Partners to provision the ISS by multiple transportation vehicles from Russia, Europe, Japan, and U.S. suppliers provide a very robust capability to safely operate and crew the ISS. Furthermore, the ISS itself is robust in design and operational capability to be operated safely without on orbit crew, as outlined in the NASA response to *Question Number 10* above.

Question 12. The Administration says it is ushering in a new era of doing business with these emerging entrepreneurs. It may be a new era but the fact is that substantial tax dollars are being funneled into these ventures both in terms of funding development work as well as funding actual missions. What is the specific analysis behind the agency’s projected costs for reliance on the commercial ventures intended to provide cargo and ultimately crewed missions to the ISS? What is the basis for confidence in the reliability of these projected cost estimates? Given the steep learning curve these new ventures are on what is to prevent their costs, and therefore their ultimate pricing, from quickly outrunning the agency’s out-year forecasts?

Answer. NASA believes that the \$6 billion provided for commercial crew in the President's budget request would be sufficient to award multiple development agreements, thus increasing the likelihood that multiple partners would succeed at developing a commercial crew vehicle. In addition, it is noteworthy to point out what the Augustine Committee said about the costs of potential crew cargo program: "Comparing the scope of providing a commercial crew capability to the cost of historical programs offers a sanity check. In the existing COTS A-C contracts, two commercial suppliers have received or invested about \$400-\$500 million for the development of a new launch vehicle and unmanned spacecraft. Gemini is the closest historical program in scope to the envisioned commercial crew taxi. In about 4 years in the early-to mid-1960s, NASA and industry human-rated the Titan II (which required 39 months), and designed and tested a capsule. In GDP-inflator-corrected FY 2009 dollars, the DDT&E cost of this program was about \$2.5-\$3 billion, depending on the accounting for test flights. These two comparatives tend to support the estimate that the program can be viable with a \$5 billion stimulus from NASA.

The Agency has not yet decided which contracting mechanism would be used for the development effort and or eventual procurement of commercial crew services. Should the Agency use a fixed-price agreement, for example, NASA's investment would be fixed and any cost overruns would be the responsibility of the commercial provider. The same can be said of the Agency's agreement with its current cargo partners, both in the development and services phases. NASA's investment in both phases is fixed and thus any cost-growth will be the responsibility of our industry partners.

Question 12a. What are the specific terms and conditions that NASA intends to levy on these new ventures, and if the agency has not developed such detailed terms, how can it with confidence provide out-year budget forecasts?

Answer. NASA is developing a plan that supports the development of commercial crew transportation providers to whom NASA could competitively award crew transportation services. On May 21, 2010, NASA issued a Request for Information (RFI) seeking information that will help NASA formulate plans for Commercial Crew Transportation as proposed in the FY 2011 budget request.

This RFI requested industry feedback to the NASA plans for certifying commercial crew vehicles for NASA services, including the Draft Commercial Human Rating Plan. In addition, the RFI sought input on the general acquisition strategy and philosophy. A second RFI is planned in the late summer time-frame for industry feedback on the ISS Service Requirements Document and Interface Requirements Document.

RFI responses were due to NASA on June 11, 2010, and NASA is in the process of reviewing the proposals received. With feedback from these proposals, NASA will finalize the remaining requirements, reference documents, and acquisition strategy so that it is prepared to issue a commercial crew solicitation upon Congressional approval of the FY 2011 President's budget request for commercial crew efforts.

Question 12b. What are the specific exposures to the American taxpayer if NASA eventually terminates the commercial contracts just like it is canceling Constellation contracts, or for that matter, if the commercial ventures fail to fulfill their end of the contract?

Answer. The potential exposure as a result of termination would depend on the terms and conditions of the instruments eventually selected to support the development, demonstration and services phases of any commercial crew transportation activity. Since NASA has not completed its acquisition strategy, we cannot currently state what those exposures are likely to be.

Question 12c. What are the specific internal controls with these vendors that are being stipulated to ensure that taxpayer dollars are being properly utilized by these contractors? In their absence, how can the public be assured that their hard earned monies are not being used to pay lobbyists or other extracurricular activities not duly authorized?

Answer. Details of the acquisition strategy have not been finalized. However, NASA can assure the Congress that all applicable Federal rules and regulations will be applied and followed regarding the contractor use of funds.

Question 13. What specific analysis is behind the \$2.5B Constellation Program termination cost figure in the FY 2011 Budget Request for FY 2011 and FY 2012? To what specific uses will those funds be applied?

Answer. The FY 2011 budget request transitions away from the Constellation Program, and in doing so, provides a total of \$2.5 billion in FY 2011 and FY 2012 for Constellation closeout and transition costs—funding that is expected to cover close-out activity associated with facilities, environmental remediation, workforce, and prime and support contracts. A portion of this funding will also be used to support

the retraining of Shuttle program contractors as that program is brought to a successful close. It should be noted, however, that at present, the breakdown of costs is not complete. The Agency is using the current budget planning activities to develop the details; and an implementation plan and coordinated communications with NASA responsible offices and current Constellation contractors are required to further refine this estimate, which is consistent with past planning experience and cost estimation for the Space Shuttle Transition and Retirement. NASA's experience with close-out of the Shuttle program will serve as a useful reference for the complexity of the tasks and the potential associated costs.

Question 14. General, you heard bipartisan concern at the CJS Appropriations Subcommittee hearing where you testified, that NASA is, in the judgment of some members of this body, willfully encouraging vendors working on the Constellation program to self-terminate contracts in spite of very clear language in last year's appropriations bill directing the agency to continue implementing the authorized program of record. The response from NASA's General Counsel to a question following that hearing claims that the agency believes it CAN terminate vendor contracts associated with the program of record based on its interpretation of the words in the appropriations bill (but that it has not done so). General, I am being charitable when I call that interpretation of Congressional intent nonsensical. It was, and is the intent of the members of this body that your agency follow the law and implement the program of record, which is Constellation, until we direct you otherwise.

Can you explain to us why, if you are faithfully implementing the program of record, we continue to hear from vendors that the agency "contemplates" contract termination and is actively suggesting that vendors need to consider their "termination liability"? Why is the agency even suggesting program termination to the vendors, in whatever context, since we have given you no indication we are going to cancel Constellation?

Answer. NASA is not doing anything unprecedented. The Agency is managing the contracts in precisely the way that is required under both the Anti-Deficiency Act and the Federal Acquisition Regulations. Please reference the Government Accountability Office Opinion B-320091, July 23, 2010, *National Aeronautics and Space Administration—Constellation Program and Appropriations Restrictions, Part II*. NASA has advised contractors that the Government is not obligated to reimburse them for any costs incurred in excess of the total amount allotted by the Government to their respective contracts.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. BARBARA BOXER TO
HON. CHARLES F. BOLDEN, JR.

Question. The three NASA centers in my state, the Jet Propulsion Laboratory (JPL), Ames Research Center, and Dryden Flight Research Center, have all been an integral part of your agency's missions, producing world class research and development in the areas of aeronautics, Earth and space sciences, biotechnology, robotics, climate change research, and the next generation of flight technology. It is important that these centers retain their highly skilled workforce and fully maintain and expand their current research programs. Will you commit to continue to fully fund all three California NASA centers?

Answer. Yes, NASA plans to fully fund all three Agency centers located in California, as stated in the FY 2011 President's budget request. NASA agrees that it is important to maintain a highly skilled workforce as well as fully maintain and expand current research programs.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. AMY KLOBUCHAR TO
HON. CHARLES F. BOLDEN, JR.

Question 1. With NASA's proposed extension of the International Space Station through 2020, do you believe it's important for NASA to continue to pursue *Ares I* as a back-up if commercial space vehicles fail to meet NASA's needs?

Answer. NASA does not support the continued development of the *Ares I* crew launch vehicle.

As outlined in my testimony, the President and his staff, as well as my NASA senior leadership team, closely reviewed the Augustine Committee report, and we came to the same conclusion as the Committee: The human spaceflight program, including *Ares I*, was on an unsustainable trajectory. Therefore, the President recognized that what was truly needed for beyond LEO exploration was game-changing technologies; making the fundamental investments that will provide the foundation

for the next half-century of American leadership in space exploration. Therefore, the FY 2011 budget request invests in commercial providers to transport astronauts to the ISS, which will allow NASA to once again focus on the most difficult technological puzzles such as building rockets that allow humans to reach other planets in days rather than months and protecting humans from radiation during interplanetary travel. NASA's FY 2011 budget request also includes investments in a new space technology research and development, and a new heavy-lift and propulsion technology development program.

NASA recognizes that the development of a commercial crew transportation capability will share the same risks that are typical in any aggressive, challenging space hardware development program. Therefore, NASA is in the process of structuring its plan to support development of a commercial crew transportation capability, should the FY 2011 budget provide funding for this activity. At this time, if budget authority is provided, NASA plans to support the development efforts of multiple providers and to provide significant technical support during the development phase. This will maximize the likelihood that selected commercial providers will successfully complete development activities and will minimize the impact to the Agency if any one commercial provider is not fully successful in its development activities. With regard to the procurement of commercial crew services, NASA is hopeful that more than one partner will be selected to supply those services, thus providing redundancy of capabilities. Should those capabilities fail to materialize on time, NASA has purchased *Soyuz* seats through 2014 and has legislative authority to purchase additional seats through mid-2016.

Question 2. The solid rocket technology used on the Space Shuttle and Ares rockets are also used in missiles that contribute to our Nation's defense. Is NASA coordinating with the Department of Defense to ensure our national security interests are also considered in this matter?

Answer. NASA will continue to work closely with our other Government partners, including the Department of Defense as planning for FY 2011 implementation moves forward.

NASA Administrator Bolden has consulted with his colleagues at the Department of Defense and the National Reconnaissance Office. In particular, the Administrator has had several meetings with Secretary Donley, General Kehler, and General Carlson, and he plans to continue to meet with them, as program decisions are made and we gain additional insight into the potential relevance to the space industrial base.

Additionally, discussions are under way at all levels about ensuring we carefully consider and maintain the space industrial base, particularly with regard to NASA's discontinued use of solid rocket fuel and motors following the cancellation of Constellation. Several recent studies in this area, coupled with current dialogue in the Government's Solid Rocket Motor Industrial Base Interagency Task Force and several other joint forums, also address the this important area and NASA will continue to work to resolve any integrated issues in these joint forums at all levels. For example, NASA is working with Defense officials to develop a plan to maintain the intellectual and engineering capacity, including key workforce skills, to support next-generation rocket motors as needed. The task force is co-chaired by the Office of the Secretary of Defense's Acquisition, Technology, and Logistics office and NASA and includes representatives from the Department of Defense, NASA, the Missile Defense Agency, the Air Force, the Army, and the Navy.

While NASA has not conducted any formal assessments in these areas, NASA has worked with Defense officials to develop a plan to maintain the intellectual and engineering capacity, including key workforce skills, to support next-generation rocket motors as needed. The task force is co-chaired by the Office of the Secretary of Defense's Acquisition, Technology, and Logistics office and NASA and includes representatives from the Department of Defense (DOD), NASA, the Missile Defense Agency, the Air Force, the Army, and the Navy. This DOD report, entitled "SRM Industrial Base Interim Sustainment Plan" was submitted to Congress on June 23, 2010.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK WARNER TO
HON. CHARLES F. BOLDEN, JR.

Question 1. The U.S. aviation industry will continue to face pressure from domestic and international stakeholders to reduce carbon emissions. Investment in aeronautics will be critical on this issue and NASA Langley is especially well positioned to be a leader on green aviation. What is the future of green aviation for NASA and

what will Langley's role be in that future? Do you see a commercial role in this industry? Also, will NASA establish a lead Center for green aviation?

Answer. NASA will continue to invest in aviation vehicle and operations research to improve fuel efficiency, lower noise levels, and reduce harmful emissions. Our goals are embodied within the *National Aeronautics R&D Plan* as updated in February 2010. Within its proposed FY 2011 aeronautics R&D portfolio, NASA has in place plans for research on advanced, highly efficient and environmentally friendly aircraft, more efficient and quieter aircraft engines, and air traffic control procedures to increase capacity and minimize delays in the air and on the ground. As one of NASA's primary aeronautics research centers, the Langley Research Center (LaRC) will continue to play key roles in green aviation research. The LaRC workforce and facilities are involved in conducting research on topics such as laminar flow for reduced airframe drag, airframe noise reduction, structural concepts for reduced airframe weight, advanced propulsion/airframe integration concepts for reduced noise and fuel burn, design of low-boom, low-emissions supersonic aircraft, and multidisciplinary systems analysis techniques to enable design of new aircraft systems.

NASA utilizes cooperative relationships with commercial industry, other Federal agencies, and academia to realize the successful execution, implementation and transition of our research. We solicit ideas and concepts from the community through NASA Research Announcements, and investigate promising technologies and operational concepts in partnership with industry and other Federal agencies. The Agency also has established close ties with other Federal agencies such as the Federal Aviation Administration to better align our research activities and support eventual transition to operational use. NASA makes the results of this research broadly available to the aeronautics community so that aircraft and propulsion system manufacturers can confidently transition these technologies into the operational environment.

NASA does not plan to establish a lead Center for green aviation research. Our green aviation research is integrated across our portfolio and is conducted within our Integrated Systems Research Program, Fundamental Aeronautics Program, and Airspace Systems Program, and takes place at the Langley, Glenn, and Ames Research Centers and at the Dryden Flight Research Center. The Langley Research Center will play an important role in the management and conduct of these research activities as it is the host center for one of the critical projects, Environmentally Responsible Aviation, and participating in all of the green aviation research activities.

Question 2. In what ways will NASA re-engineer its organization and processes to support robust commercial space transport of humans and cargo to the ISS? How will NASA insure the safety of commercially developed crew space transportation systems? Are there ways to partner between NASA and commercial firms similar to the way NASA Langley worked in collaboration with the FAA to insure the safety of commercial airlines?

Answer. Safety is and always will be NASA's first core value, so the Agency will provide significant—but not intrusive—oversight over any commercial venture, whether it be cargo or commercial. For example, NASA has a Commercial Orbital Transportation Services (COTS) Advisory Team comprised of approximately 100 NASA technical experts from across the Agency. These experts work with our partners and review partner technical and programmatic progress for each milestone and provide progress assessments to NASA's Commercial Crew Cargo Program Office. Additionally, they participate in all major design reviews providing technical review comments back to our partners. The advisory team provides another method by which NASA gains confidence that our partners will be able to perform their flight demonstrations.

One of the strengths of the COTS venture is that we let the companies do what they do best, that is developing truly unique spaceflight vehicles using innovative processes that aren't available within the Federal bureaucratic framework. NASA gives them requirements that they have to meet and the Agency ensures that they have met those requirements, but NASA tries not to dictate how they meet those requirements. For example, each COTS partner must successfully verify compliance with a detailed set of International Space Station (ISS) interface and safety requirements prior to their planned ISS berthing missions. These requirements are imposed on all Visiting Vehicles wishing to visit to the ISS. Both COTS partners are currently working with the ISS program on a daily basis to ensure they meet the ISS visiting vehicle requirements. This also helps to give NASA independent insight into their progress and it builds confidence in their abilities.

With regard to commercial crew, at no point in the development and acquisition of commercial crew transportation services will NASA compromise crew safety. Sim-

ply put, U.S. astronauts will not fly on any spaceflight vehicle until NASA is convinced it is safe to do so. NASA has unique expertise and history in this area, and a clearly demonstrated record of success in transporting crew. NASA will bring that experience to bear in the appropriate way to make sure that commercial crew transportation services are a success both programmatically, and with respect to safety. At no point in the development and acquisition of commercial crew transportation services will NASA compromise crew safety. For example, NASA will have in-depth insight of the vehicle design via NASA personnel who are embedded in the contractor's facility. Additionally, NASA will impose strict requirements and standards on all providers that will be carefully evaluated and reviewed at multiple stages before a vehicle system is certified by NASA for crewed flight.

With regard to Langley Research Center's past collaboration with the FAA, NASA is always looking for innovative ways to partner and collaborate with other Federal agencies and stakeholders, and we capture lessons learned from these partnerships and apply them, whenever possible to future ventures. It is too early to say whether NASA could establish a similar research partnership with commercial space entities, given that we are in the process of finalizing our acquisition plan for commercial crew services, should Congress approve the NASA FY 2011 budget request.

To prepare for an eventual solicitation, on May 21, 2010, NASA issued a Request for Information (RFI) seeking information that will help NASA formulate plans for Commercial Crew Transportation (CCT) as proposed in the FY 2011 budget request. This RFI requested industry feedback to the NASA plans for certifying commercial crew vehicles for NASA services, including the Draft Commercial Human Rating Plan. In addition, the RFI sought input on the general acquisition strategy and philosophy. A second RFI is planned in the late summer time-frame for industry feedback on the ISS Service Requirements Document (SRD) and Interface Requirements Document (IRD). RFI responses were due to NASA on June 18, 2010. With this feedback, NASA will finalize the remaining requirements, reference documents, and acquisition strategy so that it is prepared to issue a commercial crew solicitation upon Congressional approval of the FY 2011 President's budget request for commercial crew efforts.

Question 3. Can you give me an update of progress on initiatives to have commercial companies carry cargo to the International Space Station, and do you have enough funding in the FY11 budget to use commercial firms to partner in these efforts.

Answer. NASA's commercial crew cargo program includes two phases—the development phase which falls under the Commercial Orbital Transportation Services (COTS) program and the services phase, which falls under the Commercial Resupply Services (CRS) program.

With regard to COTS, NASA currently has two funded partners, SpaceX and Orbital Sciences, which continue to make steady progress in achieving their cargo demonstration milestones. While each has experienced some milestone delays, this is not unexpected, since both partners have aggressive, success-oriented schedules, and are facing challenges typical of a spaceflight development program. As such, NASA sees no reason to doubt either company's ability to achieve its desired objectives—that of demonstrating commercial cargo delivery to and from the International Space Station in the 2011 timeframe. More specifically, both funded COTS cargo partners have progressed through their system design milestones, all of which are paid SAA milestones. Meeting existing SAA milestones is a primary indicator of progress, and completion increases our confidence.

More specifically, SpaceX was awarded a COTS agreement in August 2006 and as of mid-July, had completed 17 of 22 negotiated milestones for a total payment of \$253 million out of \$278 million. Space X is currently scheduled to conduct its first NASA demonstration mission in September 2010, followed by two additional demonstration flights in 2011. Orbital Sciences, on the other hand, has completed 12 of 19 milestones for a total payment of \$140 million out of \$170 million, and the company is scheduled to complete its NASA demonstration mission in June 2011. If approved by Congress, the President's FY 2011 budget request will be sufficient to pay for milestones these companies expect to achieve in FY 2011. Additionally, the President's budget request includes funding to help accelerate the achievement of already-planned milestones or introduce new milestones that would ultimately improve mission success for NASA's commercial cargo effort.

SpaceX plans to launch its cargo delivery services from Cape Canaveral Air Force Station, Florida, while Orbital plans to utilize NASA launch facilities at Wallops Flight Facility in Virginia.

NASA has also signed a fixed price Commercial Resupply Services (CRS) contract with both SpaceX and Orbital. The first commercial cargo delivery by SpaceX is cur-

rently schedule for July 2011. NASA is currently in negotiations with Orbital to baseline its first commercial cargo delivery flight.

NASA is working with Orbital, the NASA Wallops Flight Facility and the Mid-Atlantic Regional Spaceport to establish the WFF as the launch processing and launch site for the Orbital Taurus II vehicle which will be used to launch the Orbital Cygnus vehicle that will carry cargo to the ISS under the CRS contract.

Question 4. How best do we expand American commercial sector launch capability and capacity to ensure a low-cost competitive launch market to compete with the Russian, Chinese and Indian space programs for market share?

Answer. Investing \$6 billion in commercial crew efforts over the next 5 years will allow NASA to focus on the forward-leaning work we need to accomplish for beyond-LEO missions. Additionally, this investment will:

- Reduce the risk of relying solely on Russia to transport astronauts to the ISS following the retirement of the Space Shuttle;
- Free up NASA resources to focus on the difficult challenges in technology development, scientific discovery, and exploration;
- Make space travel more accessible and more affordable;
- Build an enhanced U.S. commercial space industry that creates new high-tech jobs, leverages private sector capabilities, spawns other businesses and commercial opportunities, and spurs growth in our Nation's economy; and,
- Inspire a new generation of Americans by these commercial ventures and the opportunities they will provide for additional visits to space.

Additionally, NASA understands that human space exploration has driven technological advances that have made the United States more competitive in the global economy. NASA's new path forward will not surrender the United States' leadership in space but rather will enable the Nation to pursue exploration in new ways.

The FY 2011 budget request invests in commercial providers to transport astronauts to the ISS. By allowing commercial providers to provide more routine access to low-Earth orbit, NASA will once again be able to focus on the most difficult technological puzzles to solve such as building rockets that allow humans to reach other planets in days rather than months and protecting humans from radiation during interplanetary travel. NASA's FY 2011 budget request includes investments in new space technology research and development, and a new heavy-lift and propulsion technology development program. More specifically, the budget request challenges NASA to develop the necessary capabilities to send Americans to places that humans have not explored before, including longer stays at exciting new locations on the Moon, near-Earth objects, strategic deep space zones called Lagrange points, and the planet Mars and its Moons. We have not sent people beyond LEO in 38 years, and this budget gives us the great opportunity to focus on scouting and learning more about destinations to further explore our solar system and to develop the game-changing technologies that will take us there. It is important that we pursue these objectives to continue leading the world in human space exploration.

By investing in new technologies, NASA will be supporting the development of technologies and infrastructure that will allow U.S. commercial launch providers to be more competitive in the global launch marketplace, while at the same time helping NASA meet exploration and science launch services needs. For example, the FY 2011 budget request provides funding for the development of lower-cost, robust engines that could be used for future Exploration systems as well as helping power, lower-cost commercial launch vehicles. This strategy has already assisted NASA's commercial cargo partners attract international launch business, which in turn continues to support the U.S. commercial spaceflight work force.

Question 5. With the extension of the International Space Station to 2020 (and even perhaps to at least 2028 as Europeans have suggested) how ready do you think the U.S. commercial spaceflight industry is to have human-rated capability to launch either NASA or commercial astronauts by mid-decade between 2014 and 2016 from facilities like the one at Wallops Island, Virginia?

Answer. NASA agrees with the assessment of the Augustine Committee which found that, "Commercial services to deliver crew to low-Earth orbit are within reach. While this presents some risk, it could provide an earlier capability at lower initial and life-cycle costs than government could achieve." Regarding when U.S. commercial companies could be ready, NASA is targeting 2015 for commercial crew demonstration flights and 2016 for the start of operations. The commercial providers will be free to use whichever launch facilities they deem to be the most appropriate given their technical and business approaches.

Question 6. What role will private enterprise play in the development of new space propulsion systems? I understand there are some leap ahead commercial technologies that are scheduled to be flight tested as called for in the NASA FY 2011 budget.

Answer. In the FY 2011 budget request, NASA plans to begin development of new liquid propellant rocket engines for a future heavy lift launch vehicle, demonstrate a high-power solar electric propulsion system, and develop technologies and concepts for nuclear thermal propulsion. These advanced propulsion technologies will enable NASA to pursue human exploration missions beyond Earth orbit by increasing payload capability and reducing trip time and cost.

Private enterprise will play a key role in development of new space propulsion systems, in partnership with NASA. This includes a range of propulsion technologies, from large powerful engines for new Earth-to-orbit launch boosters, to small innovative propulsion systems for new suborbital launch capabilities, to efficient advanced in-space propulsion systems that could ultimately enable faster trips to Mars.

In all of these areas, NASA will partner with the private sector by soliciting proposals to develop and test advanced propulsion systems and related technologies. NASA has surveyed the technologies and capabilities available in the private sector through several recent Requests for Information. Through this process, NASA learned that several companies are actively pursuing development of advanced propulsion system concepts using their own resources.

Commercial space companies are creating innovative new propulsion systems for smaller rockets that are inexpensive, reusable, and can fly as often as four times a day. Some recent examples of this are Armadillo Aerospace and Masten Space Systems, winners of the Lunar Lander Challenge, one of NASA's Centennial Challenge incentive prizes. These firms are also partnering with NASA to test their propulsion systems. Armadillo Aerospace for example used available NASA infrastructure at White Sands to simulate flight conditions at high altitude. These emerging launch firms are also selling rocket engines on the commercial market (*e.g.*, to the Rocket Racing League). Several of these innovative entrepreneurs are conducting flight tests with their new launch systems this year. NASA plans to purchase commercial suborbital launch services from these emerging suborbital launch providers under the Flight Demonstrations Program to conduct research and technology demonstrations.

Another example is Ad Astra Rocket Company, which licensed NASA technology and has entered into a series of partnership agreements with NASA to develop the variable specific impulse magnetoplasma rocket (VASIMR). This innovative technology has the potential for much more efficiency than a conventional chemical rocket, and could double the payload mass for lunar delivery or cut the transit time to Mars in half. A demonstration of a prototype of the VASIMR on the ISS is under consideration.

Question 7. How many companies beyond Orbital Sciences Corporation and Space Technologies Corporation do you envision NASA awarding future launch contracts?

Answer. For commercial crew development agreements, NASA hopes to be able to fund multiple commercial companies. These agreements will be open to all U.S. firms, both traditional and non-traditional aerospace companies. For the services phase, NASA is hopeful that one or more commercial provider will be viable.

Question 8. The X-Prize competitions have done an incredible job of driving innovation and leveraging creativity in the private sector and from unlikely sources. Could you describe NASA's efforts, through the Centennial Challenges program or otherwise, at creating similar competition-driven technological innovation efforts?

Answer. NASA's Centennial Challenges program is dedicated to unleashing American ingenuity through prize competitions involving technical problems of interest to NASA and the Nation. The Agency believes student teams, private companies of all sizes and citizen-inventors can provide creative solutions to these technical problems. Prize competitions are a way to foster technological competitiveness, new industries and innovation across America. These competitions are open to anyone, competitors work without government support and awards are made for the best solutions that are demonstrated in real-world conditions, not for concepts or designs.

Since 2005, NASA has conducted 19 prize competitions in six technical areas and has awarded \$4.5 million to 13 different teams. On July 13, 2010, NASA announced challenges in three new technical areas: low-cost access to space, advanced automation and robotics, and energy storage.

- The Nano-Satellite Launch Challenge is to place a small satellite into Earth orbit, twice in one week, with a prize of \$2 million. The goals of this challenge

are to stimulate innovations in low-cost launch technology and to encourage creation of commercial nano-satellite delivery services.

- The Night Rover Challenge is to demonstrate a solar-powered exploration vehicle that can operate in darkness using its own stored energy. The prize purse is \$1.5 million. The objective of this challenge is to stimulate innovations in energy storage technologies of value in extreme space environments, such as the surface of the moon, or for electric vehicles and renewable energy systems here on Earth.
- The Sample Return Robot Challenge is to demonstrate a robot that can locate and retrieve geologic samples from a wide and varied terrain without human control. This challenge has a prize purse of \$1.5 million and the objective is to encourage innovations in automatic navigation and robotic manipulator technologies.

The following are some examples of how the Centennial Challenges have already spurred innovation, expanded interest in science and technology and promoted the growth of new businesses supporting government and private enterprises in aviation and space:

- The *Regolith Excavation Challenge* required teams to build mining robots that could function on the Moon. In the first year of this challenge, 4 teams competed and none were successful. The next year 16 teams came from across the country but again none were successful. In the final year of the challenge, 23 teams competed including many small robotics companies and university teams and the performance was remarkable. A team led by an undergraduate student from Worcester Polytechnic Institute won the top prize. After winning, those students immediately formed a robotics company. Over 40 teams from Hawaii to Maine competed in that challenge and each invested thousands of hours of work on a problem that will be crucial to future development in space. NASA had the opportunity to observe over 40 working prototypes of mining robots and the total NASA investment over 3 years was only \$750,000.
- The winner of the *Astronaut Glove Challenge* in 2007 was Peter Homer, who at the time was an unemployed engineer in Maine. He built his first space suit gloves on his family's dining room table and involved his children in his work. After winning the challenge, he formed a company to manufacture space suit gloves and other high-tech gear. His company is now in a partnership with others working on the next generation of spacesuits.
- The *Lunar Lander Challenge* required teams to build a reusable rocket vehicle that could complete a round trip flight, taking off and landing vertically with great accuracy. A dozen teams took up this challenge and four of them actually flew rocket vehicles. The top prizes went to Masten Space Systems of Mojave, California and Armadillo Aerospace of Caddo Mills, Texas. Both companies are pursuing commercial spaceflight ventures and they were recognized by *Aviation Week* magazine as "Persons of the Year" for 2009. NASA has purchased one of the rocket vehicles that Armadillo Aerospace built for the challenge and is using it in flight-testing of new technologies for propulsion and automatic navigation systems.
- The *Power Beaming Challenge* involves the wireless transmission of electrical power. Teams began using simple searchlights as power sources in 2005 but have now progressed to high-powered laser systems with sophisticated tracking systems. In 2009, one team won the first-level prize by transmitting power to a robot that climbed a vertical cable over half-a-mile high. The challenge will be repeated this year with the goal to complete the beam-powered vertical climb at over 10 miles per hour. NASA is interested in the technology of power beaming as a way to drive robots on the surface of the Moon and other planets from remote power stations or for advanced electric propulsion vehicles in space. The technology could also enable remote power supplies for military operations and disaster relief.
- The *Green Flight Challenge* is to build and fly an aircraft that can travel 200 miles in less than 2 hours using the energy equivalent of less than one gallon of gasoline per occupant. The challenge requires an aircraft with unprecedented efficiency that at the same time must meet stringent requirements for safety and noise reduction. The competition will be held in July 2011 but there are already nine teams working on aircraft entries. Electric, hybrid and bio-fueled aircraft are expected. Innovations derived from this challenge may help revive general aviation but find wider applications in aircraft of all sizes, in other vehicles, and for energy systems in general.

- The *Strong Tether Challenge* is perhaps the most demanding prize competition that NASA has offered. To win, a team must demonstrate in a pull test that their material is 50 percent stronger than the strongest commercially available material. There have been no winners so far but carbon-nanotube tethers have been entered in the past and advanced versions are expected at the 2010 competition. The lightweight, super-strong material than can win this challenge has the potential to revolutionize almost every field of technology.

Question 8a. What are your thoughts on additional ways to harness and leverage innovation outside of normal paths and in ways that will stimulate and involve the next generation of innovators?

Answer. NASA is constantly seeking innovative ways to engage audiences in NASA's mission and inspire the next generation of scientists, engineers, innovators, and explorers.

National competition for NASA partnership or funding of novel ideas to support STEM education are key strategies in ensuring NASA's education investments remain current with audience demand and expectations. Through the "innovations" competitive awards projects, NASA's Office of Education is offering grants or cooperative agreements to organizations with novel approaches to improving STEM education or offering educational experiences in higher education, elementary and secondary education, and global climate change education. Similarly, the Summer of Innovation is encouraging the development of local and state based STEM learning communities. These STEM support communities will help meet the needs of schools and districts by providing expertise, equipment, facilities, and STEM role models. The Summer of Innovation is also promoting student participation in STEM-based contests and competitions in which NASA scientists and engineers may provide mentoring.

Periodically, NASA also offers a competitive Request for Entrepreneurial Opportunities (REOs). Organizations selected through an REO provide a unique service, or create new product or opportunity in partnership with NASA. NASA provides content, access to facilities, interactions with scientists and engineers, but no direct funding. An REO supporting Summer of Innovation is currently open.

NASA often seeks public input on the design and distribution of new products and activities. Under the authority of *Open.gov*, NASA used IdeaScale to open a public call for ideas related to its education program. IdeaScale will be used to seek public input on features to be included in a new website promoting STEM careers for girls. NASA is considering working with the entertainment industry to improve messages about STEM careers. The Entertainment Industries Council has approached NASA to investigate novel ways of inspiring student interest and achievement in STEM by including NASA mission information in television, film, and online features. Currently in work is *Picture This: Engineering*, an opportunity for experts from the engineering fields to help the entertainment community develop positive messages about engineers and engineering.

NASA has a long history of using technology in its education programs. The Agency keeps pace with technology advances by offering activities and education experiences through media currently favored by students, including pod and vodcasts, online simulations, online games, and experiences in virtual worlds. Online professional development opportunities provide educators with the flexibility in the content and scheduling of their training needs. Examples of technologies employed by NASA to make STEM fields more approachable and attractive to students and educators include:

- Gaming: NASA's Massively Multiplayer Online STEM Learning Game, Moonbase Alpha was released in July 2010. In this game, students must complete learning objectives as they repair a damaged solar array and life support system.
- Podcasts and Vodcasts: These short programs offer information about NASA's current missions, science discoveries in the news, and technological breakthroughs. Updates on student research and internship opportunities are downloadable in podcast format.
- Virtual Worlds: Students can visit NASA virtual site and participate in launches and other activities in virtual worlds, including Teen Second Life, Farmville, OpenSim, and MoonWorld. NASA has a complete educators training facility in Second Life, on the NASA eEducation Island.
- Blogging/Social Media: NASA is making increasing use of social media including Facebook, Twitter, and blogs. NASA content and activities provided through these media are tailored by age ranges. Users can personalize their experience by choosing subjects of individual interest and relevance.

- Professional Development: Through the Digital Learning Network and the Electronic Professional Development Network projects, educators can complete self-directed or training using NASA content. Educators gain depth of understanding in topical areas and learn how to use NASA materials to inspire their students.

Interactive user communities enable NASA's student and educator audiences to engage with NASA's scientists and engineers, share ideas and best practices, identify collaborative opportunities, network, identify near peers, and benefit from mentoring relationships. NASA has established user communities within several projects and audiences:

- Higher Education: The *NASA Student Ambassador Virtual Community* engages past participants in NASA's higher education programs, encouraging mentoring, research collaboration, and recruiting of future students.
- K-12 Students: The *Online Learning Community of the NASA INSPIRE* program fosters interaction between participants, NASA subject matter experts, and peers.
- K-12 Educators: Educators in the *Endeavor Science Teacher Certificate* project participate in online coursework and use their online community as a resource for positively impacting STEM education initiatives. The newly revised *NASA Explorer Schools* features a Virtual Campus community for educators to share best practices and participate in content discussions with NASA scientists and engineers. The *NASA Educators Online Community* is a new effort to match the needs of educators, both formal and informal, with the expertise of peers and NASA's scientific and technical workforce. The *NASATalk Professional Collaborative*.
- Informal Education: NASA's *Museum Alliance* is an online community-of-practice, in which members have direct access to Agency-wide content from missions, materials, resources, teleconferences, videoconferences, artifacts and news releases in order to help them share NASA's exploration mission with the American public.

Participatory exploration in NASA's mission allows students are able to ask their own questions, utilize NASA's tools, collect information and discover answers on their own. NASA supports this type of activity in both K-12 and higher education programs.

- Remote Control of NASA Instruments: The *ISS EarthKAM* enables registered middle to remotely direct a camera on the ISS to capture real times images of Earth. The *Space Grant Internet Telescope Network* partnership of online astronomical observatories allows higher education students and faculty to gain experience using astronomical equipment locally and remotely, which includes optical and/or radio telescopes, CCD cameras, and spectrographs.
- Science, Engineering, and Launches: NASA builds STEM skills by providing hands on opportunities to build, launch, and operate payloads and conduct research using NASA's unique facilities. *Graduate Student Experiences and Undergraduate Student Research Projects* address NASA technology needs. Launch programs like *Rock On!* inspire first hand interest in NASA engineering. In July 2010, NASA announced selection of research to be conducted on the ISS. The research projects were developed by elementary and secondary students and proposed through the *Kids in Micro-g!* program.
- Accessing On-Orbit Resources: Activities like education *downlinks* and *Amateur Radio on the International Space Station* ham radio conversations allow the public to interact with astronauts as they conduct scientific and engineering activities on the ISS and Shuttle. Each year, tens of thousands of students engage with crews that work 200+ miles above the Earth.
- Proposed for FY 2011, the Office of the Chief Technologist (OCT) plans to oversee a new, innovative graduate fellowship program, which is an important part of the Space Technology Research Grants program. This fellowship program focuses on competitive selection of U.S. citizen graduate student research that shows significant promise for future application to NASA missions. This effort will train the next generation of aerospace engineers and scientists by funding NASA-related graduate student research performed on campus during the academic year, as well as research performed at NASA Centers during the summer months. Each student in this project will be matched to a NASA researcher who will serve as the student's NASA advisor. Through this experience, students will advance their STEM education, gain NASA experience and learn the research

and development processes. NASA plans to highlight this student research through a number of symposia, conference, and mission-related events over the course of the student's academic career. In addition, by bringing students to the NASA Centers for considerable periods of time and matching the student's research interests with those of a NASA advisor, we intend to rebuild the pipeline of new STEM talent needed for NASA's future missions. In FY 2011, \$30M within the Space Technology Program is planned for this new program.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. KAY BAILEY HUTCHISON TO
NORMAN R. AUGUSTINE

Question 1. Mr. Augustine, I'd like to ask you a couple of questions about the report issued by the Committee you recently led. In the report, your committee provides five primary paths forward, with two additional variants, for a total of seven "alternatives" with varying technology and destination mixes. These range from the Constellation program of record, which as I recall you found is not sustainable based primarily on funding, to an implementable program of record and several flexible path options.

Answer. Our committee concluded that the existing Constellation program, and in particular *Ares I*, was not executable because of past funding mismatches and shortfalls in future budget plans. These have caused severe schedule slips, making the program objectives (e.g., support of ISS) highly tenuous. In addition, the efficacy of establishing a lunar return as the primary program objective, as compared with a sequence of ultimately more aggressive pursuits, is questioned.

Question 1a. Do you stand by your committee's analysis of several of these as viable, implementable paths forward?

Answer. The Committee on the Review of U.S. Human Spaceflight Plans stands by its assessment that several of the options offered in our report are viable, implementable and useful paths forward—under the condition that they are funded as indicated in the report.

Question 1b. You were asked to provide at least two options that fit within the FY 2011 budget profile. As you know, the Administration provides a different budget profile in its FY 2011 Budget Request. Have you or other members of your committee revisited the analysis with the new budget profile available?

Answer. Neither the Committee as a whole nor I as an individual have assessed the impact of budget profiles other than those contained in our report or derivatives we created at the time we performed our work.

Question 1c. Has the Administration shared with you why it did not choose to faithfully follow any of the specific options this committee of experts prepared?

Answer. Our committee has not discussed with the Administration the reasons for the latter's final choice of a human spaceflight program plan, nor have I.

Question 1d. One of the key points in the report is that if a commercial crew transport path were pursued, there must be a strong independent mission assurance role for NASA. One of my concerns is the continuing dearth of detail from the Administration about how it will transition from a government-provided crew transport capability to a commercial one. What, if anything, have you seen to date that indicates the Administration's proposal would provide that strong independent mission assurance role, and what would that entail?

Answer. The Committee's options that entail commercial launches of crews are premised on: (1) NASA maintaining responsibility for certifying mission assurance, including but not limited to go/no-go authority; and (2) competition for contractor selection being open to all qualified firms, both newly-established and long-established. The NASA Administrator has indicated that NASA is prepared to commit whatever resources are necessary to carry out this responsibility.

Question 2. I want to make clear; I am hopeful for the development of our commercial capabilities. I have supported the current COTS program and am hopeful that as it moves forward we will obtain crew and cargo capabilities. But, I am also a skeptic about how far the sector has come and how fragile their business case for current activities may be.

Answer. Clearly, the launch of crews to low-Earth orbit by commercial firms entails risk—as do all space activities. U.S. industry, under NASA oversight, has in fact designed and built virtually all the Nation's space hardware to date. Given continuing oversight and safety approval authority by NASA, it appears to the Committee that commercial firms can, under the conditions noted above, safely launch crews into low-Earth orbit. It should be noted that if NASA continues to operate the Earth-to-low-Earth orbit transportation system as in the past, little funding re-

mains (under the existing budget plans) for an exploration program—particularly if the life of the ISS is extended as considered in a number of the options offered by the Committee.

Question 2a. As a former head of one of the Nation's leading commercial companies in the aviation and aerospace arena, what would happen to the business case for companies like SpaceX that are currently working hard to develop launch vehicles and crew transport capabilities if the space station were lost before the companies had fully realized the ability to service it?

Answer. In addressing this question I should emphasize in the spirit in which it was asked that I speak only for myself and not for the firm I once had the privilege of serving. It would appear to me that should the ISS not continue to at least 2020 the business case for any firm to pursue commercial launch opportunities would be extremely brittle. Similarly, if NASA were to maintain its own capability to launch such payloads, in my opinion that would cast a heavy shadow of uncertainty over the commercial business case. The hope of these firms is, of course, that a strong commercial market can be developed, but as with the early airlines, this is unlikely to be possible without some form of assured initial market on the part of the government.

Question 2b. In your judgment, are there other obvious customers besides NASA for commercially developed crew transportation capabilities? If so, what is that based on? Has there been the type of commercial market analysis I call for in my bill (S. 3068)?

Answer. Other possible customers include non-NASA government agencies, foreign governments, commercial firms and eventually space tourism. Initial emphasis will be on carrying cargo. Our committee was not privy to commercial launch firm's strategic plans other than in an overall context. This accounts for the emphasis in our report on participating firms making substantial financial investments of their own and thus "backing" their stated convictions.

Question 3. In your opening statement, you indicated that your recent Human Space Flight Review Panel could find no exploration program "worthy of a great nation" that could be accomplished without an increase in NASA's total budget of roughly \$3 billion per year—adjusted incrementally for inflation. The increased funding level in the FY 2011 Budget Request is, as you know, just a little more than \$1 billion per year. How can it be argued, then, that the proposed plan for exploration in the FY 2011 request represents an exploration program that is, indeed, worthy of a great nation?

Answer. The 2011 Budget Request provides funds that, if allocated to human spaceflight program in the manner indicated in our report, appear adequate to initiate a worthy space program. The issues, however, is the commitment of the Administration, Congress and the American People to further sustain the increased funding levels for two or more decades. Absent this, any new program will inevitably find itself in the untenable position in which the Constellation program finds itself today.

Question 4. In response to a question from Senator Nelson, you discussed the issue of the gap between the retirement of the Space Shuttle and the availability of a successor capability. You responded that "the gap was created 5 years ago," and that it is a "fait accompli." I remind you that the 2008 NASA Authorization Act included language that preserved the option to continue Shuttle flights beyond 2010, in order to enable the Administration elected in November of that year to continue to have that option available to it as part of any path forward in space exploration. Even though that provision expired at the end of April, 2009, it clearly was still possible to continue Shuttle flights beyond 2010, or flying it through 2015 would not, I assume, have been one of the options you presented to the Administration in your panel's final report. Is it not true, therefore, that "the gap" initiated by the retirement of the Space Shuttle at the end of the current manifest, as provided in the FY 2011 Budget Request, represents the impact of a decision made by the present Administration, and NOT, as you suggested, something "created" 5 years ago?

Answer. The plan to phase-out the Shuttle by September 30, 2010 was, as you note, announced several years ago. As you note, the Congress directed that the option to continue to operate the Shuttle beyond that time be maintained (until April 30, 2009). Today, hardware for two more missions exists, with the possibility of adding a third (and arguably a fourth). The budget provided to our committee in mid-2009 included no funds for continuing Shuttle operations beyond September 30, 2010. Nonetheless, our committee examined the possibility of continuing the Shuttle program and concluded that with some difficulty that could be done . . . however, we indicated that any such a continuation should be conditioned on successful completion of a new safety review. As we noted, this course would offer the advantage

of reducing the Nation's dependence upon Russian launch vehicles, and would present the disadvantage of consuming funds intended for the continuation of a beyond-low-Earth orbit exploration program. No budget in the last 5 years was adequate both to continue Shuttle operations and execute NASA's Constellation program plan. (It should be noted that the budget plan our committee was provided also contained no funds to operate the ISS beyond 2015 or to de-orbit it.)

Question 5. You stated during the hearing that one could, in fact, extend the Space Shuttle, but that "the Shuttle consumes all the money you wanted to use to develop whatever is going to replace Constellation or some version of Constellation." That connection between Shuttle costs and anything else in human spaceflight development is consistently made by the Administration, commentators, and NASA officials. Yet, is it not true that it is simply a reflection of a belief that there is no potential for growth in NASA's future funding levels—which was essentially one of the constraints placed on your review by the Charter of your Human Space Flight Review Panel—and thus there exists, now and for all time, a "zero-sum" approach to funding U.S. space exploration? Why should we accept that as a "given," particularly if our position as a world leader in space exploration and technology development could be placed at risk if we accept that funding posture?

Answer. This question strikes at the very heart of the continuing NASA dilemma: insufficient funds are available for it to develop next-generation systems while continuing to operate the existing generation of systems. This is presumably why a decision was made to discontinue funding the Shuttle program (and not provide for continuing the ISS beyond the next 5 years). The Committee strongly believes that additional funds are needed above those programmed in the years ahead if America is to have a meaningful human spaceflight program. As admitted advocates for the conduct of a human spaceflight program of which any nation could be proud, the Committee sought, and was granted by the White House, the latitude to offer options that went beyond the planned funding profile. Indeed, there is no fundamental principle that establishes the current level of funding of the human spaceflight program as the "correct" one—but there is a defensible principle that states that whatever that funding level may be, programmatic goals should not be incompatible with it.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. AMY KLOBUCHAR TO
NORMAN R. AUGUSTINE

Question. Mr. Augustine Did your Commission look at more cost effective ways to alter the Constellation program in order to continue to leverage the investment already made in it? If there was a means to find dramatic cost savings in continuing forward with Constellation such that it was sustainable, would you find that of benefit to the Nation for our goals in space exploration?

Answer. As a matter of principle, there is always inherent benefit to not changing course when an existing program is underway . . . assuming that program is workable. The committee thus began its assessment with a review of the Constellation program and found it lacking in at least two regards. The first was that it had been "underfunded" throughout its history (and projected future) such that during its four-year life it had already slipped its schedule by 3–5 years . . . and thus was incompatible with the needs of the ISS and in addition offered major delays in future exploration (*e.g.*, little was accomplished to date on a heavy-lift vehicle, landers, etc.) It should be noted that this sort of problem is not unique to the Constellation program but applies to any alternative exploration program funded at the then-projected profile. The second shortcoming, in our view, was the focus on returning to the Moon as an objective—with no significant exploration milestones in approximately the next two decades.

Regarding the possibility of finding "dramatic" cost savings in the Constellation program, our estimate of its cost closely approximated that stated by NASA at the time the program was initially approved. Hence, we find little opportunity for significant savings without substantial increases in risk.